Chapter 4 WORK, POWER AND ENERGY

- In our everyday life we use terms like work and energy.
- Term work is generally used in context to any kind of activity requiring physical or mental effort.
- But this is not the way how we define work done in physics.
- When we push or pull a heavy load or lift it above the floor then we are doing work, but a man carrying heavy load and standing still is not doing any work according to scientific definition of work.
- Another term we often use is energy. Energy is usually associated with work done in the sense that a person feeling very energetic is capable of doing lot of work.
- This way energy defined to be as capacity of doing work.
- There are many forms of energy like chemical energy, mechanical energy, electrical energy, heat energy etc. These forms of energies can be used in number of ways.
- One form of energy can be converted into another form of energy.
- In this chapter we will study about work, relation between work and energy, conservation of energy etc.

Work:

⇒ In everyday language term work is used to describe any activity in which muscular or mental effect is exerted but in physics; the word work has a special meaning.

⇒ Work is said to be done by a force. It depends on two factors: (a) force applied and (b)there must be displacement of the object. Effective component of force along the direction of displacement is $F\cos\theta$ and this component of force is responsible for the displacement of the block in the given direction

⇒ Let us apply these conditions to some practical situation;

⇒ Suppose you are pushing the wall very hard but the wall does not move in this case you are doing zero work on the wall because the displacement is zero, you may feel tired after pressing hard against the wall but from the physics point of view work done is zero.

⇒ Suppose **SAIRA** holding a bucket of water is walking on a horizontal road, according to the definition the **SAIRA** is doing no work, in this case **SAIRA** is applying an upward force equal to the weight of the bucket(object). Therefore, there is no component of force in the direction of motion (displacement) hence work done by **SAIRA** on the bucket is zero.

⇒ Work is a scalar quantity, not a vector quantity. This means that, unlike force and velocity, it has no direction, only a magnitude.

⇒ **The term *work* was introduced in 1826 by the French mathematician Gaspard-Gustave Coriolis as "weight *lifted* through a height", which is based on the use of early steam engines to lift buckets of water out of flooded ore mines.**

⇒ Thus , work done by the force **F** in in displacing the body through displacement **d** is

$$W = (|F|cos\theta)|d|$$

In equation work done is defined as the product of magnitude of displacement **d** and the component of force in the direction of displacement.

⇒ Also $W = ma.d$ → we know that acceleration is time rate of change of velocity so in term of velocity work is→ $m\frac{v}{s}d$→ you can modified this equation in different form and use it to find the required data.

⇒ Dimension of work is same as that of torque and energy.

⇒ Dimension of work is ML^2T^{-2}

⇒ The work done by constant force is

$W = \vec{F}\cdot\vec{S} = Fs\cos\theta$. IF

- $\theta = 0, W = Fs$
- $\theta = 90^0, W = 0$
- $\theta = 180^0, w < 0$
- $F = 0, w = 0$
- $s = 0, w = 0$

⇒ **Unit of work :**

- Joule or Nm or kg m^2/s^2 → SI
- erg or dyne cm or g cm^2/s^2→ C.G.S
- Foot pound → F.P.S and One foot-pound is equal to 1.35581795 joules

⇒ Work depends upon the frame of reference.

⇒ Negative work is when force acting on an object hinders the object's displacement.

⇒ If a man is pushing a box inside a moving train, the work done in the frame of train will be $\vec{F}\cdot\vec{s}$, while in the frame of ground will be $\vec{F}(\vec{s}-\vec{s_0})$where $\vec{s_0}$ is the displacement of the train relative to the ground.

⇒ Work done by conservative force does not depend upon path followed by the body.

⇒ The work done by constant force does not depend upon path.

⇒ If a particle moves in a plane curve under conservative forces, the change in kinetic energy is equal to work done on the body.

⇒ Power of heart = hρg x blood pumping by heart per second.

⇒ If a light body of mass m_1 and a heavy body of mass m_2 have same momentum, then $\frac{k_1}{k_2} = \frac{m_2}{m_1}$ where K_1 is the kinetic energy possessed by mx and K_2 is KE possessed by m_2
The lighter body has more kinetic energy.

⇒ When a porter moves with a suitcase in his hand on a horizontal level road, the work done by the lifting force or the force of gravity is zero.

⇒ Work done by a variable force is given by $dw = \vec{F}\cdot d\vec{r}$.

If

$$\vec{F} = F_x\hat{\imath} + F_y\hat{\jmath} + F_z\hat{k}$$
$$d\vec{r} = d_x\hat{\imath} + dy\hat{\jmath} + dz^k$$
$$w = \int \vec{F}\cdot d\vec{r} = \int (F_x\,dx + F_y\,dy + F_z\,dz)$$

⇒ The work done by a force $\vec{F}$ exerted by a spring on a body A, during a finite displacement of the body from $A_1(x = x_1)$ to $A_2(x = x_2)$ was obtained by writing

$$w_{1\to2} = -\int_{x_1}^{x_1} k_x\,dx \to w_{1\to2} = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_2^2.$$

⇒ The work of force F is positive when the spring is returning to its unreformed position.

⇒ The work is said to be done when the point of application of force makes the body to move. Work may be negative.

⇒ The work done by a boy lifting a bucket of water is positive, while work done by gravitational force in this case is negative.

⇒ When two springs A and B are such that $k_A>k_B$, then work done when they are stretched by the same amount, $W_A > W_B$. But when they are stretched by the same force then $W_B > W_A$.

⇒ We cam also express work done in term of rectangular components of $\vec{F}$ and $\vec{S}$:

$$\vec{F} = \hat{\imath}F_x + \hat{\jmath}F_y + \hat{k}F_z\ ;\ \vec{S} = \hat{\imath}x + \hat{\jmath}y + \hat{k}z$$
$$w = \vec{F}\cdot\vec{s} = (\hat{\imath}F_x + \hat{\jmath}F_y + \hat{k}F_z).(\hat{\imath}x + \hat{\jmath}y + \hat{k}z)$$

$$w = xF_x + yF_y + zF_z$$

⇒ Note that the work done is equal to the product of the component of force in the direction of the displacement and magnitude of the displacement, since work is scalar quantity the total work done is equal to the algebric sum of the work done.

⇒ So it is scalar product or dot product of force and displacement.

NATURE OF WORK DONE:

$$w = FS\cos\theta$$

In the above equation of work it is the term $\cos\theta$ that implies that the workd done can be

i) Positive
ii) Negative
iii) Or zero

Depending upon the value of θ

Note: Half work, $\theta = 60°$ so $W = \frac{Fd}{2}$

Case (1st): Positive work done:	Case (2nd): Negative work done:	Case (3rd): Zero work done:
⇒ If $\theta < 90°$, $\cos\theta$ is positive so that work done is positive. ⇒ In this condition there will be component of force in the direction of object's displacement. EXAMPLE: ✓ When a body falls freely under the action of gravity $\theta = 0°$ so $\cos 0° = +1$ therefore the work done by the gravitational force on the falling body or object is positive. ✓ The total work done in a stretched spring is positive because the displacement and force are in same direction $\theta = 0°$ so the work done by stretching force is positive. ✓ When a horse pulls a cart on a level road then the total work done in this case is also positive.	⇒ If $\theta > 90°$ so the $\cos\theta$ gives us negative values ⇒ in this case and there is component of force opposite to the direction of displacement so we can say the total work done is negative in this case. EXAMPLE: ✓ When a body is thrown upward then the total work done by the gravitational force on the body that is moving up is negative, because the gravitational force is downward while the displacement is upward vertically. ✓ When a person lifts a body from the ground, the work done by the (downward) force of gravity is negative. ✓ When a body is moved over a rough horizontal surface now the work done by the frictional force is negative, because frictional force opposes motion, **Work done by applied force is not negative.** ✓ When a positive charge is moved towards another positive charge	⇒ If $\theta = 90°$ so $\cos 90° = 0$ hence no work is done by the force on the body. ⇒ Work done will be zero if one of them, (i) force (ii) displacement is zero, or both is zero. EXAMPLE: ✓ When a man carrying some load on his head moves on a level road, work done by the man is zero, because the load is vertically downward and displacement is horizontal so the angle is $\theta = 90°$ so the total work done is zero. ✓ A man pushing the wall is doing no work, it because there is no displacement of the wall, $\vec{s} = 0$. ✓ In case of motion of a charged particle in a magnetic field as force $\lvert \vec{F} = q(\vec{v} \times \vec{B}) \rvert$ is always perpendicular to motion, work done by this force is always zero. ✓ When a person tries to displace a wall or heavy stone by applying a force and it does not move, then work done is zero. ✓ A weight lifter does work in lifting the weight off the

	then the work done by the electrostatic force between them is negative. **Work done by applied force is again not negative.**	ground but does not work in holding it up.

Absolute units	Gravitational units
Joule [S.I.]: Work done is said to be one Joule, when 1 Newton force displaces the body through 1 meter in its own direction. From W = F.s 1 Joule = 1 Newton ×1 metre	kg-m [S.I.]: 1 Kg-m of work is done when a force of 1kg-wt. displaces the body through 1m in its own direction. From W = F s 1 kg-m = 1 kg-wt ×1 metre = 9.81 N ×1 metre = 9.81 Joule
Erg [C.G.S.]: Work done is said to be one erg when 1 dyne force displaces the body through 1 cm in its own direction. From W = F s 1 *Erg* = 1*Dyne* ×1*cm* **Relation between Joule and erg** 1 Joule = 1 N ×1 m = 10^5 dyne ×10^2 cm = 10^7 dyne ×cm = 10^7 Erg	gm-cm [C.G.S.]: 1 gm-cm of work is done when a force of 1gm-wt displaces the body through 1cm in its own direction. From W = F s 1 gm-cm = 1gm-wt ×1cm. = 981 dyne ×1cm = 981 erg

Units : The units of work are of two types

Note that;
⇒ Work done against friction positive.
⇒ Work done by friction negative.

Work done against Friction:

i. **Along a horizontal surface:**
The work done against friction along a horizontal surface is given by;
If S is the displacement of the block then work done W is given by;

$$w = Fs\cos 0° = \mu_k mgS$$

$$where\ \mu_k \Rightarrow cofficient\ of\ kinetic\ friction\ between\ the\ surfaces$$
$$m = mass\ of\ tHe\ block, so\ mg\ is\ tHe\ weigHt\ of\ tHe\ block$$

ii. **When block is moved up the inclined plane:**
In this case the weight of the block (mg) can be resolved into two rectangular components;

a) $mg\ \sin\theta$ parallel to the inclined plane.
b) $mg\cos\theta$ perpendicular to the inclined plane

So if the block iis moved through a displacement s, up the inclined plane then the work done W iis given by;

$$W = F \times S = mg(sin\theta + \mu_k + cos\theta)S$$

Or;

$$W = mgS(sin\theta + \mu_k + cos\theta)$$

iii. **If the block is moved down the inclined plane:**
In this case the angle of inclination is less than the angle of repose.
So the work done W to move the block down the inclined plane through a displacement S is;

$$W = F \times S = mg(\mu_k cos\theta - sin\theta)S$$

Or,

$$W = mgS(\sin\theta + \mu_k + \cos\theta)$$

MCQ: a man cycles up a hill whose slope is 1 in 20, if the mass of a man and bicycle is 150 kg and the man covers a distance of 100 m along the incline plane, then what will be the work done by the man________?

i. 527 j
ii. 7350 j
iii. 3160 j
iv. 0 j

EXPLANATION:

$$work\ done\ by\ man, W = FS\cos\varphi \Rightarrow here\ F = mg\sin\theta,.., so$$
$$W = (mg\sin\theta)S\cos 0^\circ$$
$$= \left(150 \times 9.8 \times \frac{1}{20}\right) \times 100 \times 1 = 7350\ J$$

ENERGY

⇒ The energy of a body is defined as the capacity of doing work.

⇒ The unit of energy is same as that of work.

⇒ Energy can be classified further into various well defined forms such as (a) mechanical (b) heat (c) electrical, (d) atomic energy, etc.

⇒ In the case of a simple pendulum, as the pendulum vibrates there is a continuous transformation between kinetic energy and potential energy and the total energy remains conserved.

⇒ When the velocity of a body changes from u to v, the work done by the resultant force $w = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$.

⇒ The total work done by an external force $\vec{F}$ in carrying a particle from a point A to a point B along a curve C is equal to the kinetic energy gained in the process.

⇒ If $\vec{F} = k\vec{s}$ where k is a constant and $\vec{s}$ is a unit vector along the tangent to the element of arc d $\vec{s}$ on a curve, on which a particle is constrained to move under the force $\vec{F}$. Then $\vec{F}$ is non- conservative.

⇒ If a single particle is moving under a conservative field of force, the sum of the kinetic energy and potential energy is always constant.

⇒ Two bodies of mass mx (heavy) and mass m_2 (light) are moving with same kinetic energy. If they are stopped by the same retarding force, then

(a) The bodies cover the same distance before coming to rest.

(b) The time taken to come to rest is lesser for m_2 p as it has less momentum i.e., $t = \frac{p}{F}$

(c) The time taken to come to rest is more for m\ as it has greater momentum.

⇒ When a light and a heavy body have same kinetic energy, the heavy body has greater momentum $p = \sqrt{(2mk)}$ where k is kinetic energy.

⇒ When two blocks A and B, coupled by a spring on When two blocks A and B, coupled by a spring on a frictionless table are stretched and released, then kinetic energy of blocks are inversely proportional to their masses.

⇒ A body cannot have momentum without having kinetic energy.

⇒ A) Mechanical energy of a system or particle is defined as the sum of kinetic energy or potential energy. And remember kinetic energy and potential energy are the main forms of energy. Will be explained later.... i.e. E = k.e + p.e

b) A body can have mechanical energy without have potential or kinetic energy.

C) Mechanical energy of a body or a system can be negative and negative mechanical energy implies that potential energy is negative and in magnitude it is more than KE. Such a state is called bound state.

⇒ The concept of potential energy exists only in the case of conservative forces.

Kinetic energy:

⇒ Kinetic energy is the energy possessed by the body by virtue of its motion

⇒ Body moving with greater velocity would possess greater K.E in comparison of the body moving with slower velocity

⇒ Consider a body of mass m moving under the influence of constant force from newton's second law of motion

F=ma

Where a is the acceleration of the body

⇒ If due to this acceleration a, velocity of the body increases from v_1 to v_2 during the displacement d then from equation of motion with constant acceleration we have

$$v_2^2 - v_1^2 = 2ad \; or \; a = \frac{v_2^2 - v_1^2}{2d}$$

⇒ Using this acceleration in Newton's second law of motion we have

$$F = \frac{m(v_2^2 - v_1^2)}{2d} \Rightarrow Fd = \frac{m(v_2^2 - v_1^2)}{2} Fd = \frac{mv_2^2}{2} - \frac{mv_1^2}{2} \quad \rightarrow 1$$

We know that Fd is the work done by the force F in moving body through distance d

⇒ In equation 1, quantity on the right-hand side $mv^2/2$ is called the kinetic energy of the body Thus

$$K.E = \frac{mv^2}{2}$$

⇒ Finally, we can define KE of the body as one half of the product of mass of the body and the square of its speed

⇒ Thus, we see that quantity ($mv^2/2$) arises purely because of the motion of the body

⇒ In equation 1 quantity

$$K_2 = \frac{mv_2^2}{2}$$

is the final KE of the body and

$$K_1 = \frac{mv_1^2}{2}$$

is the initial KE of the body. Thus equation 7 becomes

$$W = K_2 - K_1 = \Delta K \quad \rightarrow 2$$

⇒ Where ΔK is the change in KE. Hence from equation (2), we see that work done by a force on a body is equal to the change in kinetic energy of the body

⇒ Kinetic energy like work is a scalar quantity

⇒ Unit of KE is same as that of work i.e. Joule

⇒ If there are number of forces acting on a body then we can find the resultant force, which is the vector sum of all the forces and then find the work done on the body

⇒ Again equation (2) is a generalized result relating change in KE of the object and the net work done on it. This equation can be summarized as

$$K_f = K_i + W \qquad (3)$$

which says that kinetic energy after net work done is equal to the KE before network plus network done. Above statement is also known as work-kinetic energy theorem of particles

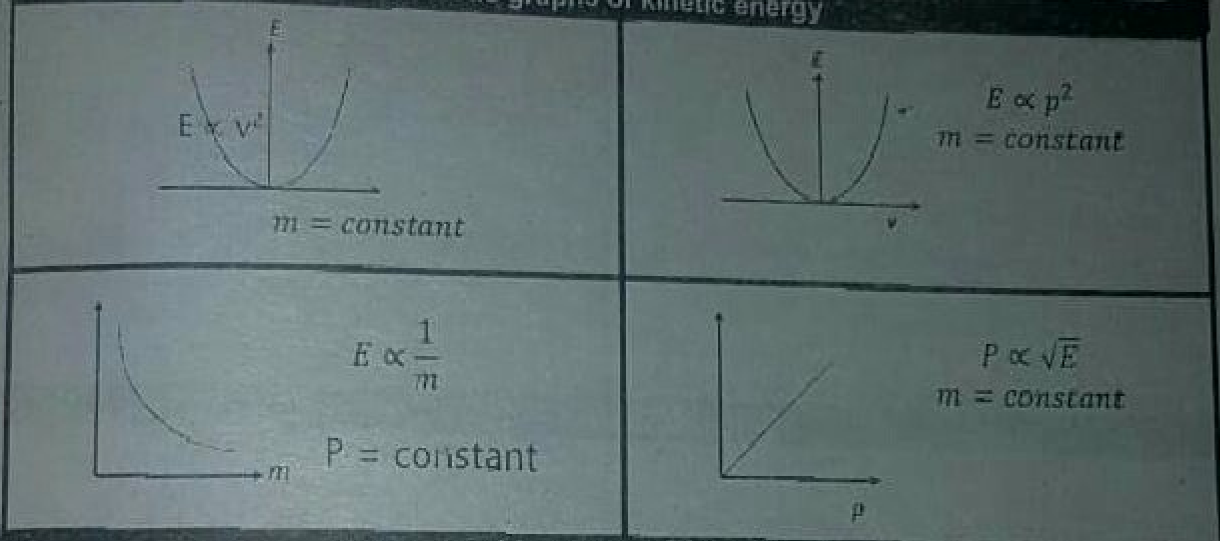
⇒ Work energy theorem holds for both positive and negative work done. If the work done is positive then final KE increases by amount of the work and if work done is negative then final KE decreases by the amount of work done.

⇒ Kinetic energy depends on frame of reference: The kinetic energy of a person of mass m, sitting in a train moving with speed v, is zero in the frame of train but $\frac{1}{2}mv^2$ in the frame of the earth.

⇒ Kinetic energy according to relativity. As we know $E = \frac{1}{2}mv^2$
But this formula is valid only for ($v << c$) If v is comparable to c (speed of light in free space = 3×10^8 m/s) then according to Einstein theory of relativity

$$E = \frac{mc^2}{\sqrt{1 - \left(v^2/c^2\right)}} - mc^2$$

Various graphs of kinetic energy



Interesting Facts about Kinetic Energy:

⇒ If you double the mass of an object, you double the kinetic energy. $k.e \propto m$
⇒ If you double the speed of an object, the kinetic energy increases by four times. $k.e \propto v^2$
⇒ The word "kinetic" comes from the Greek word "kinesis" which means motion.
⇒ Kinetic energy can be passed from one object to another in the form of a collision.
⇒ The term "kinetic energy" was first coined by mathematician and physicist Lord Kelvin.

Relation between momentum and kinetic energy:

The relation between momentum and kinetic energy is given by:

$$k \cdot e = \frac{1}{2}mv^2 \Rightarrow \frac{(mv)^2}{2m} \Rightarrow k \cdot e = \frac{p^2}{2m}$$

$$k \cdot e = \frac{1}{2}mv^2 \quad \to \quad k \cdot e \propto m \, (v = constant)$$
$$\qquad\qquad\qquad \to \quad k \cdot e \propto v^2 \, (m = constant)$$

So the ratio is

$$\frac{k \cdot E_1}{k \cdot E_2} = \frac{m_1}{m_2}$$

$$k \cdot e = \frac{p^2}{2m} \quad \to \quad k \cdot e \propto p^2 \, (m = constant)$$
$$\qquad\qquad\qquad \to \quad k \cdot e \propto \frac{1}{m} \, (p = constant)$$

So the ratio is

$$\frac{k\cdot E_1}{k\cdot E_2}=\frac{P_1^2}{p_2^2}\ or\ \sqrt{\frac{k\cdot E_1}{k\cdot E_2}}=\frac{P_1}{P_2}\ and\ \frac{k\cdot E_1}{k\cdot E_2}=\frac{m_2}{m_1}$$

Summary:

- Kinetic energy is directly proportional to mass when square of velocity is constant.
- Kinetic energy is inversely proportional to mass when square of momentum is constant.

MCQ: $P_1 : P_2 = 1:3$ for $m_1 = m_2$ if $k.e_1 = 2J$ then $k.e_2 = 18J$.

MCQ: $K.E_1 = K.E_2 = 1:3$ for $m_1 = m_2$ then $p_1:p_2 = 1\sqrt{3}$

$$k\cdot e=\frac{p^2}{2m}\rightarrow k\cdot E\times 2m=p^2\rightarrow p=\sqrt{2mk\cdot e}.$$

SO $P\propto\sqrt{k\cdot E}$ $(m = constant)$

And $p\propto m$ $(k.e = constant)$

And the ratio is given by $\frac{P_1}{P_2}=\frac{\sqrt{m_1}}{\sqrt{m_2}}$

MCQ: if m_1 = 1gm and m_2 = 4gm and $K.E_1 = K.E_2$ then which statement is correct______?

i) $P = P_2$
ii) $P_1 < P_2$ (correct)
iii) $P_1 > P_2$
iv) None of the above

SOME IMPORTANT MCQ:

i) 30% increase in momentum then % increase in kinetic energy is given by______?
 a) 69%
 b) 30%
 c) 40%
 d) 50%

Solution: initial amount is considered as 100 percent → 100% + 30% → 130% → 130/100→ 1.3→ $(1.3)^2$→ 1.3 x 1.3→ 1.69→ 169 % → remove our 100 & which we added in start→ 169 - 100→ 69%.

2nd Method:

$$k\cdot E=\left|\,2n+\frac{n^2}{100}\right|\ where\ n\ represent=nth\ increase.$$

ii) 30% Decrease in momentum then % decrease in kinetic energy is______?
 A) 51%
 b) 100%
 c) 10%
 d) 55%

Solution: 100 – 30 (due to decrease) → 70% → (0.7) →$(0.7)^2$→ 0.7 x 0.7 → 0.49 → 49 % → 100% -49% → 51 % so decrease.

2nd method:

$$k\cdot E=\left|\,2n-\frac{n^2}{100}\right|\ where\ n=nTH\ decrerase.$$

MCQ: 69 % increase in kinetic energy then % increase in momentum_______?

a) 60%
b) 30%
c) 2 %
d) 44 %

Solution: $p=\sqrt{2mk\cdot e}$→ 100 + 69% → $\sqrt{1\cdot 69}$→ 1.3 → 130% → 130 -100% → s0 30%

- Difference between Kinetic energy and momentum

kinetic energy . . .	momentum . . .
is a scalar.	is a vector

is not changed by a force perpendicular to the motion, which changes only the direction of the velocity vector.	is changed by any force, since a change in either the magnitude or the direction of the velocity vector will result in a change in the momentum vector.
is always positive, and cannot cancel out.	cancels with momentum in the opposite direction.
can be traded for other forms of energy that do not involve motion. KE is not a conserved quantity by itself.	is always conserved in a closed system.
is quadrupled if the velocity is doubled.	is doubled if the velocity is doubled.

Some conceptual points:

Figure showing point 1 and 2



i. **A spinning top**

A spinning top has zero total momentum, because for every moving point, there is another point on the opposite side that cancels its momentum. It does, however, have kinetic energy.

ii. **Why a tuning fork has two prongs**

A tuning fork is made with two prongs so that they can vibrate in opposite directions, canceling their momenta. In a hypothetical version with only one prong, the momentum would have to oscillate, and this momentum would have to come from somewhere, such as the hand holding the fork. The result would be that vibrations would be transmitted to the hand and rapidly die out. In a two-prong fork, the two momenta cancel, but the energies don't.

iii. **Momentum and kinetic energy in firing a rifle**

The rifle and bullet have zero momentum and zero kinetic energy to start with. When the trigger is pulled, the bullet gains some momentum in the forward direction, but this is canceled by the rifle's backward momentum, so the total momentum is still zero. The kinetic energies of the gun and bullet are both positive scalars, however, and do not cancel. The total kinetic energy is allowed to increase, because kinetic energy is being traded for other forms of energy. Initially there is chemical energy in the gunpowder. This chemical energy is converted into heat, sound, and kinetic energy. The gun's "backward" kinetic energy does not refrigerate the shooter's shoulder!

iv. **The wobbly earth**

As the moon completes half a circle around the earth, its motion reverses direction. This does not involve any change in kinetic energy, and the earth's gravitational force does not do any work on the moon. The reversed velocity vector does, however, imply a reversed momentum vector, so conservation of momentum in the closed earth-moon system tells us that the earth must also change its momentum. In fact, the earth wobbles in a little "orbit" about a point below its surface on the line connecting it and the moon. The two bodies' momentum vectors always point in opposite directions and cancel each other out.

v. **The earth and moon get a divorce**

Why can't the moon suddenly decide to fly off one way and the earth the other way? It is not forbidden by conservation of momentum, because the moon's newly acquired momentum in one direction could be canceled out by the change in the momentum of the earth, supposing the earth headed the opposite direction at the appropriate, slower speed. The catastrophe is forbidden by conservation of energy, because both their energies would have to increase greatly

vi. **Momentum and kinetic energy of a glacier**

A cubic-kilometer glacier would have a mass of about 10^{12} kg. If it moves at a speed of 10^{-5} m/s, then its momentum is 10^7 kg · m/s. This is the kind of heroic-scale result we expect, perhaps the equivalent of the space shuttle taking off, or all the cars in LA driving in the same direction at freeway speed. Its kinetic energy, however, is only 50 J, the equivalent of the calories contained in a poppy seed or the energy in a drop of gasoline too small to be seen without a microscope. The surprisingly small kinetic energy is because kinetic energy is proportional to the square of the velocity, and the square of a small number is an even smaller number.

Potential energy

⇒ Scottish scientist William Rankine first coined the term potential energy in the 19th century

⇒ The concept of potential energy goes all the way back to Ancient Greece and the philosopher Aristotle.

⇒ Potential energy is the energy stored in the body or a system by virtue of its position in field of force or by its configuration.

⇒ Force acting on a body or system can change its PE

⇒ Few examples of bodies possessing PE are given below

i) Stretched or compressed coiled spring

ii) Water stored up at a height in the Dam possess PE

iii) Any object placed above the height H from the surface of the earth possess PE

⇒ Potential energy is denoted by letter U

⇒ In next two topics we would discuss following two example of PE

i)P.E of a body due to gravity above the surface of earth

ii) P.E of the spring when it is compressed or elongated by the application of some external force

⇒ $Potential\ energy = mgh$ → it means→

P.e depend upon mass

It depend upon value of g.

It also depend upon height because p. e is all about position.

Some important interpretations:

Vertical motion: $W = K.E + P.E$ (if friction $f = 0$)

Or $w = \Delta k \cdot E + \Delta p \cdot E$

Upward motion: $K.E_{lost} = P.E_{gain}$ (if friction $f = 0$)

Or $K.Elost = P.E_{gain} + wf$ $(f \neq 0)$

Downward motion: $P.Elost = K.E_{gain}$ (if friction $f = 0$)

Or $P.E_{lost} = K.E_{gain} + W_f$ (if friction$(f \neq 0)$)

Sources of energy: i. POTENTIAL ENERGY

Chemical potential: **Explanation:** Chemical potential energy is the energy contained within the bonds between atoms. These bonds can take many different forms, including energy derived from carbohydrates in food to energy stored in gaso-line. Food energy allows us to do work and gasoline	**Elastic Potential:** **Explanation:** Elastic potential energy is the energy stored within a stretched compressed object, such as an elastic band or a car bumper. Pole-vaulters store elastic energy in the pole and then use it to glide over a bar.
Electric Potential: **Explanation:** Since opposite charges attract, electric potential energy can be stored by a	**Gravitational Potential:** **Explanation:** Gravitational potential energy is the energy of position. A roller-coaster cart

separation of positive and negative charges. Electric potential energy does work as the electrons move from negatively to positively charged objects.	poised at the top of a large hill contains gravitational energy that will result in the cart's passengers' enjoyment of the ride.

Nuclear: **Explanation**: Nuclear energy consists of the energy stored within the nucleus of an atom. When extremely large atoms, such as uranium or plutonium, undergo fission, or split in two, tremendous amounts of energy are released. Nuclear power stations use this energy to generate electric energy. Research continues in an attempt to harness energy released when two extremely small atoms undergo fusion, or join together.

ii. KINETIC ENERGY:

Mechanical Kinetic: **Explanation:** Kinetic energy is the energy of motion. Any object that is moving has kinetic energy, from atoms and molecules to cars, to planets.	**Sound:** **Explanation:** Sound energy travels through a substance as a wave. As a sound wave passes through, the atoms or molecules of the substance vibrate back and forth, colliding with the adjacent atoms or molecules. Sound vibrations cause a person's eardrums to vibrate.
Thermal: **Explanation**: Thermal energy is the energy of random motion of the particles that make up an object or system. A bathtub filled with 65°C water has much more thermal energy than a teacup of water at the same temperature.	**Radiant:** **Explanation:** Radiant energy travels as an electromagnetic wave. Although electromagnetic waves do not involve a moving mass, they do carry energy through space. In fact, in some applications, radiant energy is treated as massless particles or packets of energy called "photons." Radiant energy from the Sun supplies Earth with all of the energy required to sustain life. It also drives all weather systems.

WORK ENERGY THEOREM:

⇒ According to this theorem the work done by the net force acting on a body is equal to the change in kinetic energy of the body.

⇒ This theorem have a simple meaning,

Case (1st): when a force is applied on a body in the direction of motion of a body, the speed and hence kinetic energy of a body increases according to this theorem the increase in kinetic energy of the body is equal to the work done by the force on the body.

Case (2nd): If the force is applied on a body in the direction opposite to its motion, the kinetic energy of body decreases, the decrease in kinetic energy of a body is equal to the work done by the body against the retarding force.

⇒ In above both the cases the kinetic energy of the body is equa to the work done (positive or negative work done).

⇒ According to this theorem;

$$work\ done = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$$

The ratios are;

$$\frac{1}{2}mv_1^2 = F \times S_1\ and\ \frac{1}{2}mv_2^2 = F \times S \Rightarrow \frac{v_2^2}{v_1^2} = \frac{S_2}{S_1} \Rightarrow if\ v_2\ is\ unknown;$$

$$v_2 = \sqrt{\frac{S_2}{S_1}} \times v_1$$

We can write it also;

$$work\ done = \frac{m}{2}(v_2^2 - v_1^2)$$

Also;

$$work\ done, -FS = -\frac{1}{2}mv_0^2 \Rightarrow s = \frac{v_0^2}{2g\sin\theta}$$

So;

$$Net\ work\ done\ = change\ in\ kinetic\ energy.$$

⇒ If net force does positive work on a body then kinetic energy of the body increases.
⇒ If net force does negative work on a body the kinetic energy of the body decreases.
⇒ If work done on a body is zero then kinetic energy of the body remains the same (it does not change).

Gravitational PE near the surface of the earth:

⇒ All bodies fall towards the earth with a constant acceleration known as acceleration due to gravity
⇒ Consider a body of mass m placed at height h above the surface of the earth
⇒ Now the body begins to fall towards the surface of the earth and at any time t, it is at height h(h' < h) above the surface of the earth
⇒ During the fall of the body towards the earth a constant force F=mg acts on the body where direction of force is towards the earth
⇒ Work done by the constant force of gravity is

$$W = F.d$$
$$W = mg(h - h')$$
$$W = mgh - mgh \rightarrow (1)$$

From equation (1), we can clearly see that work done depends on the difference in height or position

⇒ So, a potential energy or more accurately gravitational potential energy can be associated with the body such that

$$U = mgh$$

Where h is the height of the body from the reference point

⇒ if

$$U_i = mgh, U_f = mgh'\ \ or$$
$$W = U_i - U_f = -\Delta U \rightarrow (2)$$

The potential energy is greater at height h and smaller at lower height h

⇒ We can choose any position of the object and fix it zero gravitational PE level.PE at height above this level would be mgh
⇒ The position of zero PE is chosen according to the convenience of the problem and generally earth surface is chosen as position of zero PE
⇒ One important point to note is that equation (2) is valid even for the case when object of mass m is thrown vertically upwards from height h to $h'(h' < h)$

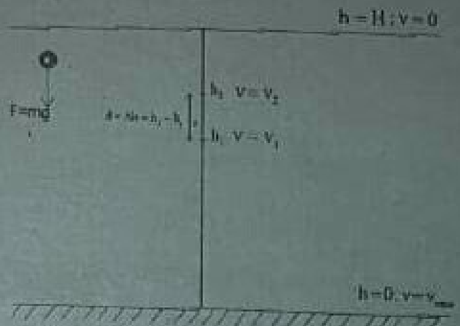
Points to keep in mind

✓ If the body of mass m is thrown upwards a height h above the zero-reference level then its PE increase by an amount mgH
✓ If the body of mass falls vertically downwards through a height h, the PE of body decreases by the amount mgH

Conversion of Gravitational PE to KE:

⇒ Consider an object of mass placed at height H above the surface of the earth
⇒ By virtue of its position the object possesses PE equal to mgH

- ⇒ When this object falls it begins to accelerate towards earth surface with acceleration equal to acceleration due to gravity g
- ⇒ When object accelerates it gathers speed and hence gains kinetic energy at the expense of gravitational PE
- ⇒ To Analyze this conversion of PE in KE consider the figure given below



Conversion of PE into KE when object of mass m falls from height H

- ⇒ Now at any given height h, PE of the object is given by the $U = mgh$ and at this height speed of the object is given by v
- ⇒ Change in KE between two height h_1 and h_2 would be equal to the work done by the downward force

$$\frac{mv_1^2}{2} - \frac{mv_2^2}{2} = mgh \quad (1)$$

Where d is the distance between two heights, here one important thing to note is that both force and are in the same downwards direction

- ⇒ Corresponding change in Potential energy

$$U_1 - U_2 = mg(h_1 - h_2) = mgh \quad (2)$$

Here the negative sign indicates the decrease in PE which is exactly equal to the gain in KE

- ⇒ From equation (1) and (2)

$$\frac{mv_1^2}{2} - \frac{mv_2^2}{2} = U_2 - U_1 \quad or \quad K.E_1 + P.E_1 = K.E_2 + P.E_2$$

- ⇒ Thus total energy of the system KE and gravitational PE is conserved. There is a conversion of one form of energy into another during the motion but sum remains same
- ⇒ This can be proved as follows

At height Velocity of the object is zero

$$\Rightarrow at\ H = H, v = 0 \Rightarrow K.E = 0$$

$$so\ K..E + P.E = mgH$$

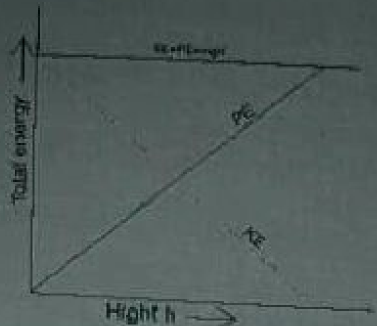
$$\Rightarrow at\ H = h, v = v \Rightarrow K.E = \frac{mv^2}{2} = mg(H - h) and\ U = mgH$$

$$so\ K.E + P.E = mgH$$

$$\Rightarrow at\ H = 0, v = v_{max} \Rightarrow K.E = \frac{mv_{max}^2}{2} = mgH$$

$$so\ K.E + P.E - mgH$$

- ⇒ This shows that total energy of the system is always conserved because total energy $KE + PE = mgH$, which remains same as plotted in the figure given below



Plots of KE and PE during the free fall of an object of mass m

⇒ We know conclude that energy can neither be produced nor be destroyed. It can only be transformed from one form to another

PE of the spring:

⇒ To study this, consider an electric spring of negligibly small mass. One end of the spring is attached to the rigid wall and another end of spring is attached to a block of mass m which can move on smooth frictionless horizontal surface

⇒ Consider the figure given below

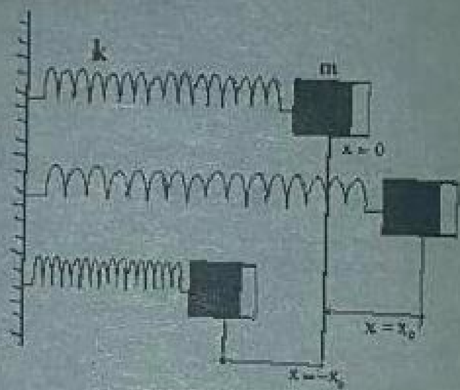


Figure 6, PE of a spring

Here upstretched or un compressed position of the spring is taken at x=0

⇒ We now take the block from its upstretched position to a point P by stretching the spring

⇒ At this point P restoring force is exerted by the spring on the block trying it bring it back to the equilibrium position.

⇒ Similar restoring force develops in the spring when we try to compress it

⇒ For an ideal spring, this restoring force F is proportional to displacement x and direction of restoring force is opposite to that displacement

⇒ Thus, force and displacement are related as

$$F \propto x \quad or \; F = -kx \quad (1)$$

Where K is called the spring constant and this equation (1) is known as Hook's law.

Negative sign indicates that force oppose the motion of the block along x

⇒ To stretch a spring, we need to apply the external force which should be equal in magnitude and opposite to the direction of the restoring force mentioned above i.e. for stretching the spring

$$F_{ext} = kx$$

Similarly, for compressing the spring

$$-F_{ext} = -Kx$$
$$or \; F_{ext} = Kx$$

(both F and x are being negative)

⇒ Work done in both elongation and compression of spring is stored in the spring as its PE which can be easily calculated

⇒ If the spring is stretched through a distance x from its equilibrium position x=0 then

$$W = \int F_{ext} dx$$

Since both F_{ext} and dx have same direction Now

$$W = \int k_x dx$$

On integrating within the limits x=0 to x=x
We have

$$W = \frac{kx^2}{2} \quad (2)$$

⇒ This work done is positive as force is towards the right and spring also moves towards the right

⇒ Same amount of external is done on the spring when it is compressed through a distance x

⇒ Work done as calculated in equation (2) is stored as PE of the spring. Therefore

$$U = \frac{kx^2}{2} \quad (3)$$

Conservation of energy of spring mass system:

⇒ Again, consider the figure (above) where we have stretched the spring to a distance x_0 from its equilibrium position x=0

⇒ If we release the block then speed of the block begin to increase from zero and reach its maximum value at x=0 (equilibrium position)

⇒ Assuming that there is no dissipation of energy due to air resistance and frictional forces, whole of the PE is converted in KE

⇒ This means gain in KE is exactly equal to the loss in PE

⇒ After reaching the equilibrium position at x=0, the block then crosses the equilibrium position, it speed begin to decreases until it reaches the point $x=-x_0$

⇒ This would happen if whole the conversion between KE and PE is perfect without any dissipation effect

⇒ Now at $x=-x_0$ PE of the block is maximum, KE is zero and the restoring force again pulls the block towards its equilibrium position. This way block would keep on oscillating

⇒ From all discussion, we see that total mechanical energy (KE+PE) of the system always remain constant which is equal to $Kx_0^2/2$

⇒ We can analyze this as follows

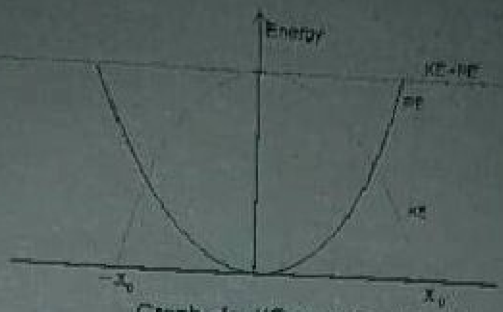
$$x = x_o, \quad v = 0, \quad K.E = 0, \quad P.E = \frac{kx_o^2}{2}, \quad T.E = \frac{kx_o^2}{2}$$

$$x = x, \quad v = v, \quad K.E = \frac{mv^2}{2} = \frac{k(x_o^2 - x^2)}{2}, \quad P.E = \frac{kx^2}{2}, \quad T.E = \frac{kx_o^2}{2} x = 0,$$

$$v = \frac{v_{max}^2}{2} = \frac{kx_o^2}{2}, \quad P.E = 0, \quad T.E = \frac{kx_o^2}{2}$$

$$x = x_o, \quad v = 0, \quad K.E = 0, \quad P.E = \frac{kx_o^2}{2}, \quad T.E = \frac{kx_o^2}{2}$$

Graph of KE and PE are shown below in figure



Graphs for KE and PE of a spring

- ⇒ From above graph we can easily conclude that when KE increases PE decreases and when PE increase KE decrease but total energy of the system remains constant
- ⇒ Above discussed case is the ideal case when other dissipated forces like frictional forces or air resistance are assumed to be absent
- ⇒ However, in realty some part of the energy of the system is dissipated due to these resistive forces and after some time system loses all its energy and come to rest.

Field: Region or space where body experience force.
Force experienced by a body is known as field force.

Conservative Forces/Field:

- ⇒ Consider the gravitational force acting on a body. If we try to move this body upwards by applying a force on it then work is done against gravitation
- ⇒ Consider a block of mass m being raised to height h vertically upwards as shown in fig (a). Work done in this case is mgH
- ⇒ Now we make the block travel the path given in figure (b) to raise its height h above the ground. In this path work done during the horizontal motion is zero because there is no change in height of the body due to which there would be no change in gravitational PE of the body and if there is no change in the speed KE would also remain same
- ⇒ Thus, for fig (b) if we add up the work done in two vertical paths the result we get is equal to mgH

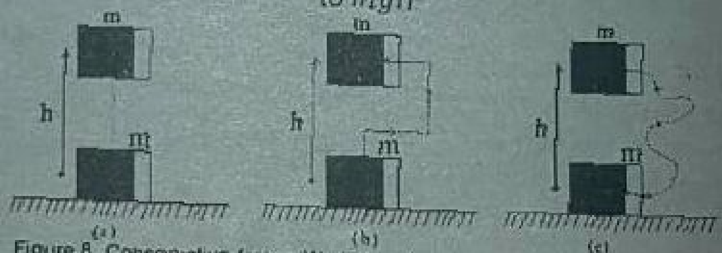


Figure 8. Conservative force:- Work done in raising a block of mass m to height h is independent of the path taken

- ⇒ Again if we move the block to height h above the floor through an arbitrary path as shown in fig (c), the work-done can be calculated by breaking the path into elementary horizontal and vertical portions
- ⇒ Now work done along the horizontal path would be zero and along the vertical paths its add up to mgh
- ⇒ Thus, we can say that work done in raising on object against gravity is independent of the path taken and depends only on the initial and final position of the object
- ⇒ Now we are in position to define the conservative forces

" If the work done on particle by a force is independent of how particle moves and depends only on initial and final position of the objects then such a force is called conservative force"

Gravitational force, electrostatic force, elastic force and magnetic forces are conservative forces

- ⇒ Total work done by the conservative force is zero when particle moves around any closed path returning to its initial position

⇒ Frictional forces and viscous forces are examples of non-conservative forces as these forces always oppose the motion and result in loss in KE.

⇒ Concept of PE is associated with conservative forces only. No such PE is associated with non-conservative forces like frictional forces.

Principle of conservation of energy

⇒ We have already learned that $KE + PE$ remains constant or conserved in absence of dissipative power

⇒ As discussed in case of spring mass system in reality dissipative forces like friction and air resistance are always present and some of the energy of the system gets dissipated in the force of heat energy by increasing the internal energy of the spring

⇒ This continues until system finally comes to rest

⇒ If one can somehow measure this energy, the sum of KE, PE and this internal (or energy dissipated) would remain constant. This can be extended to all types of energy

⇒ Energy cannot be created or destroyed. It can only be transferred from one form to another form. Total energy in a closed system always remains constant

⇒ This is the law of conservation of energy although empirical one but it has never been found violated.

Machine:

"Device which minimized human effect by modifying force or distance".

- Cannot generate energy
- *For real machine input > output (due to energy loss).*
- *For ideal machine input = output (No energy loss).*

Input force: Human effect to do work applied force on machine.

Output force: Force by machine on load.

Mechanical advantage: How much machine minimized human effort which is mechanical advantage of machine.

Ideal mechanical advantage: Ratio of distance moved by load with machine to distance moved without machine.

$$IMA = \frac{d_1}{d_2} \quad OR \quad IMA = \frac{d_1}{f_1}$$

$$d_1 > h$$

$$\text{always} \rightarrow IMA > 1$$

Real mechanical advantage: Ratio of force used with a machine to the force used without machine.

$$RMA = \frac{w_y}{w} \Rightarrow RMA = \frac{Effort}{weight}$$

$$Since\ w_1 < w \Rightarrow R.M.A < 1$$

$$Eficiency = \frac{Real\ mechanical\ advantage}{Ideal\ mechanical\ advantage}$$

⇒ Represented by eta (η).

⇒ $\eta < 1 \rightarrow RMA < IMA$

⇒ Machine with 100% efficiency is not possible.

⇒ Transformer have high efficiency but not 100 %

⇒ When output = input then it shows that efficiency is 100%.

⇒ Efficiency of automobile is only 15%

⇒ Light bulb has an efficiency of 2% the other 98 % are wasted in the form of different energy.

Absolute gravitational potential energy:

⇒ Energy at a point in gravitational field with respect to a point which is at infinity (zero potential) is known as Absolute gravitational potential energy.

⇒ Or it may be defined as potential energy at a single point in a gravitational field with respect to zero potential point.

⇒ Kinetic energy is actually the work done against frictional force similarly potential energy is work done against gravity.

⇒ "U "From earth to infinity or above the surface of earth is

$$u = \frac{GMm}{r}.$$

⇒ So potential energy is $p \cdot E \propto h.$

⇒ *so*

$$u \propto -\frac{1}{r}$$

⇒ *If we displace the body from surface of earth of radius* Re" Then we replace "r" by Re

⇒ *Actually it is the work done against gravity so its value is always taken is negative.* Like

$$u = -\frac{GmMe}{Re}$$

⇒ Now gravitational potential at any point is defined as → "The potential energy per unit mass at the point which is at distance r from the surface of earth and is given by

$$v_r = -\frac{GMe}{R_e}.near\ surface\ of\ earth$$

⇒ Or the gravitational potential energy or self-energy for a system of n masses is given by $u =$

$$-\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{GM_i m_i}{r_{ij}} \quad i > j$$

⇒ The change occurred in potential energy when a point mass m is moved vertically upwards through a height h from earth's surface.

$$\Delta u = \frac{mgRh}{(R+h)}$$

⇒ Case 1 → h << R → $\Delta u = \frac{mgh}{1+\frac{h}{R}} = mgh.$

⇒ Case 2 → h >> R → $\Delta u = \frac{mgR}{1+\frac{R}{h}} = mgR.$

⇒ The body gravitational potential energy is negative near the earth surface and become less negative (greater) as we move away from the earth surface.

⇒ The maximum potential energy of a body is zero (o) at $r = \infty$, this is in agreement with our previous observations that objects have more gravitational potential energy as they move away from the earth surface.

⇒ Since the force between the body and earth is attractive an external agent must do positive work to increase the separation of a body from the earth. The external work done increase the potential energy as the body is taken away from earth surface.

⇒ The gravitational potential energy of the body of a mass 'm' at a distance r_1 from the center of the earth is;

$$U_1 = -\frac{GMm}{r_1}$$

The gravitational potential energy of the body at a distance r_2 from the center of the earth ($r_2 > r_1$) is;

$$U_2 = -\frac{GMm}{r_2}$$

change in potential energy is:

$$\Delta P \cdot E = U_2 - U_1 \quad (U_2 = \frac{GMm}{r_2}) - (U_1 = \frac{GMm}{r_1}) = GMm(\frac{1}{r_1} - \frac{1}{r_2})$$

Since $r_1 < r_2$, the change in potential energy is positive, it means that if the body is moved away from the surface of the earth the gravitational potential energy of the body increases, conversely the gravitational potential energy of the body decreases as it is brought closer to the earth.

Intensity and Potential:

⇒ The intensity of earth gravitational field at a point is equal to the acceleration that a unit mass would experience when placed at that point.

⇒ The intensity of earth gravitational field at any point simply mean the acceleration due to gravity at that point, on the surface of the earth $E=g=9.8m/s^2$.

⇒ Gravitational field at a point distance r from a point mass m is $E = \frac{Gm}{r^2}$ towards the point mass and r gravitational potential is $v = -\frac{Gm}{r}$.

⇒ Spherical shell or hollow sphere:

$$Case\ i: ➔ r > R ➔, where\ R\ is\ radius\ of\ spherical\ shell.\ E = \frac{Gm}{r^2}\ and\ v = -\frac{Gm}{r}.$$

$$Case\ ii: ➔ r < R, E = 0, V = -\frac{Gm}{r}.$$

⇒ A uniform solid sphere of mass m:

$$Case\ I: ➔ r > R, E = \frac{Gm}{r^2}\ and\ V = -\frac{Gm}{r}.$$

$$Case\ ii: ➔ r < R, E = \frac{Gm}{R^3} r\ and\ v = -\frac{Gm}{2R^3}(3R^2 - r^2).$$

⇒ So, the intensity of gravitational field is zero at infinity in other words we can say that acceleration due to gravity is zero at infinity.

What is the main difference between absolute potential energy and gravitational potential energy?

In most cases when we talk about gravitational potential energy in simple physics problems we are talking about relative gravitational potential energy. So, if we raise a 5 kg object by a height of 2 m, we did 100 J of work and hence, the object has a gravitational potential energy of 100 J... relative to the initial position. In both the initial and the final position, the object was under the influence of the gravitational field.

Absolute gravitational potential is the work done when we move an object from infinity to a point in the gravitational field. At infinity, we set the gravitational potential energy to be zero and then as we move the object closer and closer to the source, the gravitational potential energy decreases and becomes more and more negative. Therefore, absolute gravitational potential energy is gravitational potential energy relative to infinity.

You will often see this show up in orbital mechanics problems. Similar terminology is used for electric fields and electric potential energies.

Power:

⇒ Rate of doing work is called power. If velocity vector makes an angle θ with the force vector, then $P = \vec{F} \cdot \vec{v} = Fv\cos\theta$

⇒ The potential energy per unit time is called power;

$$work\ done = mgh \Rightarrow As\ power = \frac{work}{Time} \Rightarrow Power = \frac{mgh}{T}$$

$$also\ Power = \frac{E}{t} = \frac{Potential\ energy}{t} = \frac{mgh}{t}$$

$$and\ power = \frac{E}{t} = \frac{kinetic\ energy}{t} = \frac{\frac{1}{2}mv^2}{t}$$

⇒ If velocity or height is unknown you can find it from above equations.

⇒ We know that $F = mgsin\theta \Rightarrow power = F.v \Rightarrow Power = mgsin\theta.v$

$$P = \frac{Work}{Time\ or\ power} = \frac{Energy}{Time}$$

As $Work = F.s$

$$So\ P = \frac{W}{t} \rightarrow P = \frac{F.S}{t} \rightarrow P = F.v$$

$$p = F.v \Rightarrow Force = \frac{Power}{velocity}$$

⇒ Power in case of kinetic energy $= \frac{mv^2}{2T}$

⇒ The ratio is;

$$\Rightarrow \frac{p_1}{p_2} = \frac{w_1}{w_2} \Rightarrow \frac{p_1}{p_2} = \frac{t_2}{t_1} \Rightarrow \frac{p_1}{p_2} = \frac{F_1}{F_2} \Rightarrow \frac{p_1}{p_2} = \frac{v_1}{v_2}$$

⇒ Unit of power:

- ✓ erg / sec ➔ CGS system.
- ✓ Horse power ➔ 1 horse power = 746 watts, 555 ftp sec ➔ Fps system.
- ✓ J / sec or watt ➔ SI system.
- ✓ Commercial unit of power is kilo watt hour ➔ Botu (Board of trade unit).
  1 Kwh = 1 B.O.T.U = 1 unit = $10^3 \times 3.6 \times 10^3$ watt-sec ➔ 3.6×10^6 watt-sec➔ 3.6×10^6 J

⇒ **In rotatory motion:** $p = \tau \frac{d\theta}{dt} = \tau\omega$.

⇒ If a body moves along a rough horizontal surface, with a velocity v, then the power required is $p = \mu mgv$

⇒ (a) If a block of mass m is pulled along the rough inclined plane of angle θ then power is $p = (mg \sin\theta + \mu mg \cos\theta)v$.

⇒ (b) If a same block is pulled along the smooth inclined plane with constant velocity v, the power spent is $p = (mg \sin\theta)v$.

⇒ The slope of the work-time graph (work along Y-axis and time along X-axis) gives us the instantaneous power.

⇒ The area under power time graph gives us the total work done during the considered time.

CONCEPTUAL: (why the unit of power is horse power)



The unit, the watt, was named in honor of the Scottish engineer, James Watt, who made such great improvements in the steam engine that it hastened the Industrial Revolution. The ability to do work did not change, but the rate at which the work could be accomplished did. Watt did experiments with strong dray horses and determined that they could lift 550 pounds a distance of one foot in 1 s. He called this amount of power one horsepower (hp). Converting to SI units, 1 hp is equivalent to 746 W. What do you think your horsepower is? Design a simple experiment that you could use to determine your horsepower.

Escape Velocity:

It is defined as minimum speed of projection with which if a body is projected upwards, then it does not return back to earth.

Mathematically: $v_{es} = \sqrt{\left(\frac{2GM}{R}\right)} = \sqrt{2gR}$

where M = mass of planet

⇒ Escape velocity is independent of the mass of projectile but it depends on the mass of planet.

⇒ Escape velocity does not depend on angle of projection.

- ⇒ Escape velocity depend upon mass of the planet.
- ⇒ It depends upon size or radius of the planet.
- ⇒ The trajectory of a projectile projected from a very tall tower parallel to the surface of earth depends upon its velocity v as follows:

Velocity of projectile	Projection
$v < \frac{v_e}{\sqrt{2}} = v_0$	Projectile does not revolve around earth. It falls back on the surface of earth
$v = \frac{v_e}{\sqrt{2}} = v_0$	Projectile revolves around the earth in circular orbit.
$\frac{v_e}{\sqrt{2}} < v < v_e$	Projectile moves around earth in elliptical path
$v = v_e$	It escapes from the gravitational field of earth in parabolic path.
$v > v_e$	It escapes from the gravitational field of earth in a hyperbolic path.

- ⇒ If a particle of mass m is dropped from the end of tunnel along diameter of earth, then the motion of the particle is S.H.M. having angular frequency of $\omega = \sqrt{(\frac{g}{R})}$.
- ⇒ The time period of longest pendulum on the surface of earth is given by $T = 2\pi\sqrt{(\frac{R}{g})}$ where R = 6400 km and g = 9.8 m/sec^2.
- ⇒ Escape velocity = 11.2 km /sec
- ⇒ In other conversion escape velocity = 25000 miles h^{-1}.
- ⇒ Also escape velocity = 40320 km h^{-1}.
- ⇒ For any other planet escape velocity is given by:

$$Vesc = \sqrt{\frac{2GM_p}{R_p}}$$

Note that:

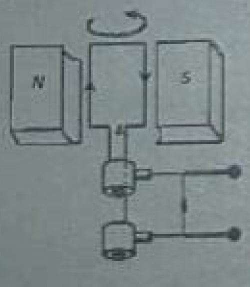
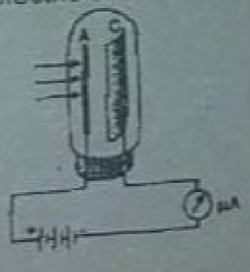
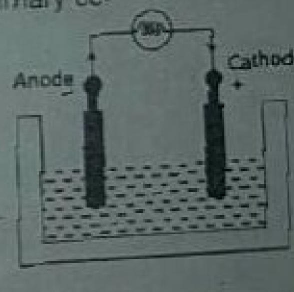
The orbital velocity of satellite close to earth surface is

$$v = \sqrt{gR}$$

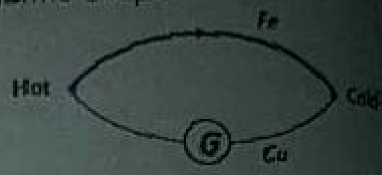
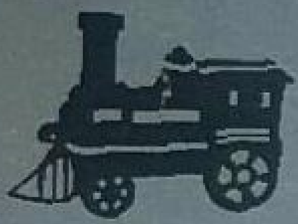
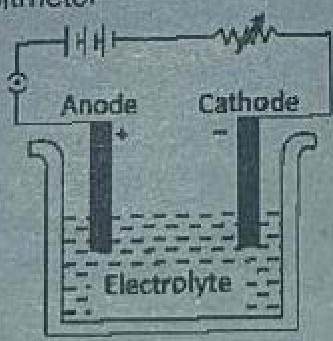
$$Now\ escape\ velocity = v_e = \sqrt{2gR} = \sqrt{2}v = 1.41\ v$$

Thus escape velocity is only 41 % greater than the orbital velocity of a satellite close to earth surface.

⇒ The escape velocity of sun is 618 km/s.

Mechanical→electrical	Light →Electrical	Chemical →electrical
Dynamo 	Photoelectric cell 	Primary cel 

Chemical →heat	Sounds →Electrical	Heat →electrical

Coal Burning 	Microphone 	Thermo-couple 
Heat → Mechanical	**Electrical → Mechanical**	**Electrical → Heat**
Engine 	Motor 	Heater 
Electrical → Sound	**Electrical → Chemical**	**Electrical → Light**
Speaker 	Voltmeter 	Bulb 

Formula Sheet

S/N	QUANTITY	EQUATION
1)	Work	$W = \vec{F}.\vec{s} = Fs\cos\theta$
2)	conservative field	$W_{net} = 0$
3)	Power	$P = \frac{W}{t} \Rightarrow \frac{E}{t}$ $P = F.v \Rightarrow Fv\cos\theta$ If $E = K.E$ the; $P = \frac{K.E}{t} = \frac{mv^2}{2t}$ $t = \frac{mv^2}{2p}$ or $v = \sqrt{\frac{2Pt}{m}}$ If $E = P.E$ the; $P = \frac{P.E}{t} = \frac{mgh}{t}$
4)	kinetic energy	$k.e = \frac{1}{2}mv^2$
5)	potential energy	$p.e = mgh$
6)	relation between momentum and K.E	$K.E = \frac{P^2}{2m}$ or $P = \sqrt{2mK.E}$
7)	work energy principle	$W = \Delta E$
8)	Absolute gravitational potential energy	$P.E_g = -\frac{GM_e m}{r}$ $r = R_e + h$
9)	Absolute gravitational potential	$v_g = -\frac{GM_e}{r}$
10)	Escape velocity	$v_{esc} = \sqrt{\frac{2GM_e}{R_e}}$ or $v_{esc} = \sqrt{2gR_e}$

Some Important Points and Tricks:

1) The area under the force-displacement graph is equal to the work done.
2) Work done by gravitation or electric force does not depend on the path followed. It depends on the initial and final positions of the body. Such forces are called conservative. When a body returns to the starting point under the action of conservative force, the net work done is zero
3) Work done against friction depends on the path followed. Viscosity and friction are not conservative forces. For non-conservative forces, the work done on a closed path is not zero.
4) Work done is path independent only for a conservative field.
5) Work done depends on the frame of reference.
6) Work done by a centripetal force is always zero
7) Energy is a promise of work to be done in future. It is the stored ability to do work
8) Energy of a body is equal to the work done by the body and it has nothing to do with the time taken to perform the work. On the other hand, the power of the body depends on the time in which the work is done.
9) When work is done on a body, its kinetic or potential energy increases.
10) When the work is done by the body, its potential or kinetic energy decreases.

11) According to the work energy theorem, the work done is equal to the change in energy. That is $W = \Delta E$.
12) Work energy theorem is particularly useful in calculation of minimum stopping force or minimum stopping distance. If a body is brought to a halt, the work done to do so is equal to the kinetic energy lost.
13) Potential energy of a system increases when a conservative force does work on it.
14) The kinetic energy of a body is always positive.
15) When the momentum of a body increases by a factor n, then its kinetic energy is increased by factor n^2.
16) If the speed of a vehicle is made n times, then its stopping distance becomes n^2 times.
17) The total energy (including mass energy) of the universe remains constant.
18) One form of energy can be changed into other form according to the law of conservation of energy. That is amount of energy lost of one form should be equal to energy or energies produced of other forms.
19) Kinetic energy can change into potential energy and vice versa. When a body falls, potential energy is converted into kinetic energy.
20) Pendulum oscillates due to conversion of kinetic energy into potential energy and vice versa. Same is true for the oscillations of mass attached to the spring.
21) Conservation laws can be used to describe the behavior of a mechanical system even when the exact nature of the forces involved is not known.
22) Although the exact nature of the nuclear forces is not known, yet we can solve problems regarding the nuclear forces with the help of the conservation laws.
23) Violation of the laws of conservation indicates that the event cannot take place.
24) The gravitational potential energy of a mass m at a height h above the surface of the earth (radius R) is given by $U = \frac{mgh}{1+\frac{h}{R}}$ where $h \ll R$, we find $U = mgh$
25) Energy associated with a photon $E = h\nu = hc/\lambda$, where h = planck's constant, ν = frequency of the light wave, c = velocity of light, λ = wave length.
26) Mass and energy are inter-convertible. That is mass can be converted into energy and energy can be converted into mass.
27) A mass m (in kg) is equivalent to energy (in J) which is equal to mc^2 where c = speed of light.
28) A stout spring has a large value of force constant, while for a delicate spring, the value of spring constant is low.
29) The term energy is different from power. Whereas energy refers to the capacity to perform the work, power determines the rate of performing the work. Thus, in determining power, time taken to perform the work is significant but it is of no importance for measuring energy of a body.
30) Collision is the phenomenon in which two bodies exert mutual force on each other.
31) The collision generally occurs for very small interval of time.
32) Physical contact between the colliding bodies is not essential for the collision.
33) The mutual forces between the colliding bodies are action and reaction pair. In accordance with the Newton's third law of motion, they are equal and opposite to each other.
34) The collision is said to be elastic when the kinetic energy is conserved.
35) In the elastic collisions the forces involved are conservative.
36) In the elastic collisions, the kinetic or mechanical energy is not converted into any other form of energy.
37) Elastic collisions produce no sound or heat.
38) There is no difference between the elastic and perfectly elastic collisions.
39) In the elastic collisions, the relative velocity before collision is equal to the relative velocity after the collision. That is $\vec{u_1} - \vec{u_2} = \vec{v_2} - \vec{v_1}$ where $\vec{u_1}$ and $\vec{u_2}$ are initial velocities and $\vec{v_1}$ and $\vec{v_2}$ are

the velocities of the colliding bodies after the collision. This is called Newton's law of impact.

40) The collision is said to be inelastic when the kinetic energy is not conserved.
41) In the perfectly inelastic collision, the colliding bodies stick together. That is the relative velocity of the bodies after the collision is zero.
42) In an elastic collision of two equal masses, their kinetic energies are exchanged.
43) During collision, velocity of the colliding bodies changes.
44) Linear momentum is conserved in all types of collisions.
45) Perfectly elastic collision is a rare physical phenomenon.
46) Collisions between two ivory or steel or glass balls are nearly elastic.
47) The force of interaction in an inelastic collision is non-conservative in nature.
48) In inelastic collision, the kinetic energy is converted into heat energy, sound energy, light energy etc.
49) In head on collisions, the colliding bodies move along the same straight line before and after collision.
50) Head on collisions are also called one dimensional collisions.
51) In the oblique collisions the colliding bodies move at certain angles before and/or after the collisions.
52) The oblique collisions are two dimensional collisions.
53) When a heavy body collides head-on elastically with a lighter body, then the lighter body begins to move with a velocity nearly double the velocity of the heavier body.
54) When a light body collides with a heavy body, the lighter body returns almost with the same speed.
55) If a light and a heavy body have equal momenta, then lighter body has greater kinetic energy
56) Area under the F - v graph is equal to the power dissipated
57) Power dissipated by a conservative force (gravitation, electric force etc.) does not depend on the path followed. I' depends on the initial and final position of the body.
58) Power dissipated against friction depends on the path followed.
59) An engine pulls a train of mass m with constant velocity. If the rails are on a plane surface and there is no friction, the power dissipated by the engine is zero.
60) Loss in kinetic energy = gain in potential energy
61) Gain in kinetic energy = loss in potential energy.
62) The food we eat in one day has about the same energy as 0.33 litres of petrol experiment shows that the average power of a man walking upstairs in an ordinary speed is only about 0.33 KW.
63) Power is directly proportional to Energy.
64) Power is inversely proportional to t.
65) Power have a unit of js^{-1}
66) THE pull of the moon does not only pull the sea up and down but it pulls land up and down as much as 0.25m.
67) There are mainly two sources of Energy➔ i) Non-renewable sources ii) Renewable sources of energy.
68) As their names indicate that one can be renewed and the other one cannot be renewed.
69) Non-renewable sources cause more pollution in a comparison with renewable sources.
70) Renewable sources are more important than non-renewable because they can be renewed.
71) Over 85% of energy use in the world is from non- renewable sources.
72) Fossil fuels are the most commonly used types of non-renewable sources.
73) The three main types of fossil fuels are Coal, oil and natural gas.
74) Coal is the most abundant fossil fuel in the world with an estimated reserve of one trillion metric tons.
75) The softest coal which is composed of 50% carbon which also has the lowest energy output is called lignite.
76) In now a days world is consuming coal at a rate of about 5 billion metric tons per year.
77) Natural gas is also used in a process of making fertilizer.
78) Energy from bio mass, energy from waves, energy from tides solar energy

etc are the example of renewable sources of energy.

79) Electrical energy is the scientific form of electricity.

80) Nuclear energy which is renewable provide almost 16% energy of the world.

81) Efficiency is defined as the ratio of the useful output to the total input.

82) This can be calculated using energy or power values as long as you are consistent.

83) Efficiency is normally expressed as a percentage.

84) If out-put = input then it shows the efficiency is 100%.

85) Conservative forces: → Work done in a closed path is zero. → Independent of path → No dissipation of energy. Example → Gravitational force, electric force, magnetic force, elastic spring force.

86) Non conservative forces: → Work done does not equal to zero → Path dependent → dissipation occur. Example → Friction force, air resistance force, propulsion of rocket

MULTIPLE CHOICE QUESTIONS

1) A bread gives a boy of mass 40kg an energy of 21kJ. If the efficiency is 28% then the height can be climbed by him using this energy is
a) 22.5 m b) 15 m c) 10 m d) 5 m

2) If a body of mass 200g falls from a height 200m and its total potential energy is conserved into kinetic energy, at the point of contact of the body with the surface, then decrease in potential energy of the body at the contact is ..
a) 900 J b) 600 J
c) 400 J d) 200 J

3) A body of mass 100 gm is rotating in a circular path of radius r with constant velocity. The work done in one complete revolution is
a) (r/100) J b) (100/r) J
c) zero d) 100 rJ

4) The mass of two substances are 25g and 81g respectively. If their kinetic energies are same then the ratio of their momentum is ..
a) 9:5 b) 1:4
c) 5:9 d) 2:1

5) A force (3i + 4j) newton acts on a body and displaced it by (3i + 4j) meter. The work done by this force is ...
a) 5 J b) 25 J
c) 10 J d) 30 J

6) If a water falls from a dam into a turbine wheel 19.6 m below, then the velocity of water at the turbines is (take $g=9.8\ m/s^2$)
a) 9.8 m/s b) 19.6 m/s
c) 39.2 m/s d) 98.0 m/s

7) Two bodies of masses 'm' and '4m' are moving with equal kinetic energy. Then the ratio of their linear momentum will be...
a) 1:1 b) 2:1 c) 4:1 d) 1:2

8) A spring 40 mm long is stretched by applying a force. If 10N force is required to stretch the spring through one mm, then work done in stretching the spring through 40mm is
a) 24 J b) 8 J
c) 56 J d) 54 J

9) A particle of mass 10g is kept on the surface of a uniform sphere of mass 100kg and radius 10cm. Find the work done against the gravitational force between them to take the particle far away from the sphere
($G=6.67\times10^{-11}\ Nm^2/kg^2$)
a) 3.33×10^{-10} J b) 13.34×10^{-10} J
c) 6.67×10^{-10} J d) 6.67×10^{-9} J

10) If the force applied is F and the velocity gained is 'v', then the power developed is____?
a) v/F b) Fv
c) Fv^2 d) F / v

11) A bullet is fired from a riffle. If the riffle recoils freely, then the kinetic energy of the rifle will be..
a) same as that of bullet
b) more than that of bullet
c) less than that of bullet
d) none of these

12) When a ball is thrown up vertically with velocity v_o it reaches a maximum height of h. If one wishes to triple the maximum height then the ball should be thrown with velocity..

a) $v_o\sqrt{3}$ b) $3v_o$
c) $9v_o$ d) $(3/2)v_o$

13) A force of 250 N is required to lift a 75 kg mass through a pulley system. In order to lift the mass through 3 m, the rope has to be pulled through 12m. The efficiency of system is
a)50% b) 75%
c)33% d)90%

14) The potential energy of a system increases if work is done
a) upon the system by a non conservative force
b) by the system against a conservative force
c) by the system against a non conservative force
d)upon the system by a conservative force

15) kinetic energy acquired by a mass (m) in traveling distance (s) starting from rest under the action of a constant force is directly proportional to
a) $1/\sqrt{m}$ b) $1/m$
c) $\sqrt{m}$ d) m_0

16) A particle of mass m1 is moving with a velocity v_1 and another particle of mass m_2 is moving with a velocity v_2. Both of them have the same momentum but their different kinetic energies are E_1 and E_2 respectively. If $m_1 > m_2$ then
a) $E_1=E_2$ b) $E_1 < E_2$
c) $E_1 / E_2=m_2 / m_1$ d) $E_1 > E_2$

17) A ball of mass 2 kg and another of mass 4 kg are dropped together from a 60 feet tall building. After a fall of 30 feet each towards earth, their respective kinetic energies will be in the ratio of
a) $1 : \sqrt{2}$ b) $\sqrt{2} : 1$
c) 1:4 d) 1:2

18) An engine pumps water continuously through a hose. Water leaves the hose with a velocity v and m is the mass per unit length of the water jet. What is the rate at which kinetic energy is imparted to water?
a) mv^2 b) $\frac{1}{2}(m2v^2)$
c) $\frac{1}{2}(m v^2)$ d) $\frac{1}{2}(m v^3)$

19) A bullet of mass 10g leaves a rifle at an initial velocity of 1000m/s and strikes the earth at the same level with a velocity of 500 m/s. the work done in joules overcoming the resistance of air will be
a)375 b) 3750
c)5000 d)500

20) How much water, a pump of 2kW can rise in one minute to height of 10 m, taking g=10 m/s2
a) 1000 liters b) 1200 liters
c)100 liters d)2000 liters

21) The kinetic energy acquired by a mass (m) in traveling distance starting from rest under the action of constant force is directly proportional to [
a) $1 / \sqrt{m}$
b) $1/m$
c) $\sqrt{m}$
d)m0

22) Two body of masses m and 4m are moving with equal kinetic energy. The ratio of their linear momentum is equal to ..
a) 4:1 b) 1:1
c) 1:2 d) 1:4

23) Two bodies with kinetic energies in the ratio 4:1 are moving with equal linear momentum. The ratio of their masses is
a) 1:2 b) 1:1
c) 4:1 d) 1:4

24) When a ling spring is stretched by 2cm its potential energy is U. If the spring is stretched by 10cm, the potential energy stored in it will be
a) 25U b) U/5
c) 5U d) 10U

25) Water falls from a height of 60m at the rate of 15kg/s to operate a turbine. The losses due to frictional force are 10% of energy. How much power is generated by the turbine? ($g=10\ m/s^2$)
a)8.1 kW b) 10.2 kW
c)12.3kW d)7.0Kw

26) A body of mass 1 kg is thrown upwards with a velocity 20 m/s. It momentarily comes to rest after attending a height of 18m . How much energy is lot due to air friction($g=10m/s^2$
a)30J b) 40J
c)10J d)20J

27) A body projected vertically from the earth reaches a height equal to radius of earth before returning to earth. The power exerted by gravitational force is greatest
a)at the highest position of the body

b) at the instant just before the body hits the earth
c)it remains constant all through
d)at the instant just after the body is projected

28) If a machine is lubricated with oil
a) the mechanical advantage of the machine increases
b) the mechanical efficiency of the machine increases
c)both its mechanical advantage and efficiency increases
d)its efficiency increases, but its mechanical advantage decreases

29) A wire suspended vertically from one of its ends is stretched by attaching a weight of 200N to the lower end. The weight stretched the wire by 1mm. Then the elastic energy stored in the wire is
a) 0.2 J b) 10 J
c) 20 J d) 0.1 J

30) A particle moves in a straight line with retardation proportional to its displacement. Its loss of kinetic energy for any displacement x is proportional to
a) x b) e^x c)x^2 d)log x

31) A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle, the motion of the particles take place in the plane. It follows that
a) its kinetic energy is constant
b) its acceleration is constant
c)its velocity is constant
d)it moves in a straight line

32) If the unit of force and length each be increased by four times, then the unit of energy is increased by
(a) 16 times (b) 8 times
(c) 2 times (d) 4 times

33) A man pushes a wall and fails to displace it. He does
(a) Negative work
(b) Positive but not maximum work
(c) No work at all (d) Maximum work

34) You lift a heavy book from the floor of the room and keep it in the book-shelf having a height 2 m. In this process you take 5 seconds. The work done by you will depend upon
(a) Mass of the book and time taken
(b) Weight of the book and height of the book-shelf
(c) Height of the book-shelf and time taken
(d) Mass of the book, height of the book shelf and time taken

35) A body of mass m kg is lifted by a man to a height of one meter in 30 sec. Another man lifts the same mass to the same height in 60 sec. The work done by them are in the ratio
(a) 1 : 2 (b) 1 : 1
(c) 2 : 1 (d) 4 : 1

36) A body of mass 10 kg is dropped to the ground from a height of 10 metres. The work done by the gravitational force is (g = 9.8 m / sec^2)
(a) – 490 Joules (b) + 490 Joules
(c) – 980 Joules (d) + 980 Joule

37) A force of 5 N, making an angle θ with the horizontal, acting on an object displaces it by 0.4m along the horizontal direction. If the object gains kinetic energy of 1J, the horizontal component of the force is
(a) 1.5 N (b) 2.5 N
(c) 3.5 N (d) 4.5 N

38) The work done against gravity in taking 10 kg mass at 1m height in 1sec will be
(a) 49 J (b) 98 J
(c) 196 J (d) None of these

39) The energy which an e^{-1} acquires when accelerated through a potential difference of 1 volt is called
(a) 1 Joule (b) 1 Electron volt
(c) 1 Erg (d) 1 Watt

40) A 50kg man with 20kg load on his head climbs up 20 steps of 0.25m height each. The work done in climbing is
(a) 5 J (b) 350 J
(c) 100 J (d) 3430 J

41) In an explosion a body breaks up into two pieces of unequal masses. In this
(a) Both parts will have numerically equal momentum
(b) Lighter part will have more momentum
(c) Heavier part will have more momentum
(d) Both parts will have equal kinetic energy

42) Which of the following is a unit of energy
(a) Unit (b) Watt
(c) Horse Power (d) None

43) If force and displacement of particle in direction of force are doubled. Work would be
(a) Double (b) 4 times
(c) Half (d) ¼ times

44) A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle, the motion of the particle takes place in a plane. It follows that
(a) Its velocity is constant
(b) Its acceleration is constant
(c) Its kinetic energy is constant
(d) It moves in a straight line

45) A ball of mass m moves with speed v and strikes a wall having infinite mass and it returns with same speed then the work done by the ball on the wall is
(a) Zero (b) mv J
(c) m/v J (d) v/m J

46) The kinetic energy acquired by a body of mass m is travelling some distance s, starting from rest under the actions of a constant force, is directly proportional to
(a) m^0 (b) m
(c) m^2 (d) $\sqrt{m}$

47) A man starts walking from a point on the surface of earth (assumed smooth) and reaches diagonally opposite point. What is the work done by him
(a) Zero (b) Positive
(c) Negative (d) Nothing can be said

48) It is easier to draw up a wooden block along an inclined plane than to haul it vertically, principally because
(a) The friction is reduced
(b) The mass becomes smaller
(c) Only a part of the weight has to be overcome
(d) 'g' becomes smaller

49) Two bodies of masses 1 kg and 5 kg are dropped gently from the top of a tower. At a point 20 cm from the ground, both the bodies will have the same
(a) Momentum (b) Kinetic energy
(c) Velocity (d) Total energy

50) Two bodies of masses m_1 and m_2 have equal kinetic energies. If p_1 and p_2 are their respective momentum, then ratio $p_1 : p_2$ is equal to?
(a) $m_1 : m_2$ (b) $m_2 : m_1$
(c) $\sqrt{m_1} : \sqrt{m_2}$ (d) $m_1^2 : m_2^2$

51) Work done in raising a box depends on
(a) How fast it is raised
(b) The strength of the man
(c) The height by which it is raised
(d) None of the above

52) A light and a heavy body have equal momenta. Which one has greater K.E
(a) The light body (b) The heavy body
(c) The K.E. are equal (d) Data is incomplete

53) A body at rest may have
(a) Energy (b) Momentum
(c) Speed (d) Velocity

54) The kinetic energy possessed by a body of mass m moving with a velocity v is equal to $\frac{1}{2}mv^2$, provided?
(a) The body moves with velocities comparable to that of light
(b) The body moves with velocities negligible compared to the speed of light
(c) The body moves with velocities greater than that of light
(d) None of the above statement is correct

55) If the momentum of a body is increased n times, its kinetic energy increases
(a) n times (b) 2n times
(c) $\sqrt{n}$ times (d) n^2 times

56) When work is done on a body by an external force, its
(a) Only kinetic energy increases
(b) Only potential energy increases
(c) Both kinetic and potential energies may increase
(d) Sum of kinetic and potential energies remains constant

57) From a stationary tank of mass 125000 pound a small shell of mass 25 pound is fired with a muzzle velocity of 1000 ft/sec. The tank recoils with a velocity of
(a) 0.1 ft/sec (b) 0.2 ft/sec
(c) 0.4 ft/sec (d) 0.8 ft/sec

58) A bomb of 12 kg explodes into two pieces of masses 4 kg and 8 kg. The velocity of 8kg mass is 6 m/sec. The kinetic energy of the other mass is
(a) 48 J (b) 32 J
(c) 24 J (d) 288 J

59) A body of mass 2 kg is thrown up vertically with K.E. of 490 joules. If the acceleration due to gravity is 9.8 m / s² then the height at which the K.E. of the

body becomes half its original value is given by
(a) 50 m (b) 12.5 m
(c) 25 m (d) 10 m

60) Two masses of 1 gm and 4 gm are moving with equal kinetic energies. The ratio of the magnitudes of their linear momenta is
(a) 4 : 1 (b) 2 : 1
(c) 1 : 2 (d) 1 : 16

61) If the K.E. of a body is increased by 300%, its momentum will increase by
(a) 100% (b) 150%
(c) 300% (d) 175%

62) A light and a heavy body have equal kinetic energy. Which one has a greater momentum?
(a) The light body
(b) The heavy body
(c) Both have equal momentum
(d) It is not possible to say anything without additional information

63) If the linear momentum is increased by 50%, the kinetic energy will increase by
(a) 50% (b) 100%
(c) 125% (d) 25%

64) If the K.E. of a particle is doubled, then its momentum will
(a) Remain unchanged (b) Be doubled
(c) Be quadrupled (d) Increase $\sqrt{2}$ times

65) If the stone is thrown up vertically and return to ground, its potential energy is maximum
(a) During the upward journey
(b) At the maximum height
(c) During the return journey
(d) At the bottom

66) A body of mass 2 kg is projected vertically upwards with a velocity of 2 m sec^{-1}. The K.E. of the body just before striking the ground is
(a) 2 J (b) 1 J
(c) 4 J (d) 8 J

67) The energy stored in wound watch spring is
(a) K.E. (b) P.E.
(c) Heat energy (d) Chemical energy

68) Two bodies of different masses m_1 and m_2 have equal momenta. Their kinetic energies E_1 and E_2 are in the ratio
(a) $\sqrt{m_1} : \sqrt{m_2}$ (b) $m_1 : m_2$
(c) $m_2 : m_1$ (d) $m_1^2 : m_2^2$

69) If the kinetic energy of a body increases by 0.1%, the percent increase of its momentum will be
(a) 0.05% (b) 0.1%
(c) 1.0% (d) 10%

70) If velocity of a body is twice of previous velocity, then kinetic energy will become
(a) 2 times (b) ½ times
(c) 4 times (d) 1 times

71) In which case does the potential energy decrease
(a) On compressing a spring
(b) On stretching a spring
(c) On moving a body against gravitational force
(d) On the rising of an air bubble in water

72) Two bodies of masses m and 2m have same momentum. Their respective kinetic energies E_1 and E_2 are in the ratio
(a) 1 : 2 (b) 2 : 1
(c) $1 : \sqrt{2}$ (d) 1 : 4

73) If a lighter body (mass and velocity) and a heavier body (mass and velocity) have the same kinetic energy, then
(a) $M_2V_2 < M_1V_1$ (b) $M_2V_2 = M_1V_1$
(c) $M_2V_1 = M_1V_2$ (d) $M_2V_2 > M_1V_1$

74) If the kinetic energy of a body becomes four times of its initial value, then new momentum will
(a) Becomes twice its initial value
(b) Become three times its initial value
(c) Become four times its initial value
(d) Remains constant

75) A bullet is fired from a rifle. If the rifle recoils freely, then the kinetic energy of the rifle is
(a) Less than that of the bullet
(b) More than that of the bullet
(c) Same as that of the bullet
(d) Equal or less than that of the bullet

76) If the water falls from a dam into a turbine wheel 19.6 m below, then the velocity of water at the turbine is ($g = 9.8$ m/s^2)
(a) 9.8 m/s (b) 19.6 m/s
(c) 39.2 m/s (d) 98.0 m/s

77) Two bodies of masses 2m and m have their K.E. in the ratio 8 : 1, then their ratio of momenta is
(a) 1 : 1 (b) 2 : 1 (c) 4 : 1 (d) 8 : 1

78) A bomb of 12 kg divides in two parts whose ratio of masses is 1 : 3. If kinetic energy of smaller part is 216 J, then momentum of bigger part in kg-m/sec will be
(a) 36 (b) 72
(c) 108 (d) Data is incomplete

79) If the increase in the kinetic energy of a body is 22%, then the increase in the momentum will be
(a) 22% (b) 44% (c) 10% (d) 300%

80) If a body of mass 200 g falls from a height 200 m and its total P.E. is converted into K.E. at the point of contact of the body with earth surface, then what is the decrease in P.E. of the body at the contact ($g = 10\ m/s^2$)
(a) 200 J (b) 400 J (c) 600 J (d) 900 J

81) The kinetic energy of a body of mass 2 kg and momentum of 2 Ns is
(a) 1 J (b) 2 J (c) 3 J (d) 4 J

82) A ball is released from certain height. It loses 50% of its kinetic energy on striking the ground. It will attain a height again equal to
(a) One fourth the initial height
(b) Half the initial height
(c) Three fourth initial height
(d) None of these

83) An ice cream has a marked value of 700 kcal. How many kilowatt hour of energy will it deliver to the body as it is digested
(a) 0.81kWh (b) 0.90kWh
(c) 1.11kWh (d) 0.71kWh

84) A particle of mass 'm' and charge 'q' is accelerated through a potential difference of 'V' volt. Its energy is
(a) qV (b) mq V (c) $\left(\frac{q}{m}\right)V$ (d) $\frac{q}{mV}$

85) Two bodies moving towards each other collide and move away in opposite directions. There is some rise in temperature of bodies because a part of the kinetic energy is converted into
(a) Heat energy (b) Electrical energy
(c) Nuclear energy (d) Mechanical energy

86) A bomb of mass 3.0 Kg explodes in air into two pieces of masses 2.0kg and 1.0 kg. The smaller mass goes at a speed of 80 m/s. The total energy imparted to the two fragments is
(a) 1.07 kJ (b) 2.14 kJ
(c) 2.4 kJ (d) 4.8 kJ

87) A particle of mass m_1 is moving with a velocity v_1 and another particle of mass m_2 is moving with a velocity v_2. Both of them have the same momentum but their different kinetic energies are E_1 and E_2 respectively. If $m_1 > m_2$ then?
(a) $E_1 < E_2$ (b) $\frac{E_1}{E_2} = \frac{m_1}{m_2}$
(c) $E_1 > E_2$ (d) $E_1 = E_2$

88) A ball of mass 2kg and another of mass 4kg are dropped together from a 60 feet tall building. After a fall of 30 feet each towards earth, their respective kinetic energies will be in the ratio of
(a) $\sqrt{2} : 1$ (b) 1 : 4 (c) 1 : 2 (d) $1 : \sqrt{2}$

89) Four particles given, have same momentum which has maximum kinetic energy
(a) Proton (b) Electron
(c) Deuteron (d) α –particles

90) A body moving with velocity v has momentum and kinetic energy numerically equal. What is the value of v
(a) 2m/s (b) $\sqrt{2}$m/s (c) 1m/s (d) 0.2 m/s

91) Which among the following, is a form of energy
(a) Light (b) Pressure
(c) Momentum (d) Power

92) If a shell fired from a cannon, explodes in mid air, then
(a) Its total kinetic energy increases
(b) Its total momentum increases
(c) Its total momentum decreases
(d) None of these

93) If a force F is applied on a body and it moves with a velocity v, the power will be
(a) F x v (b) F / v
(c) F / v^2 (d) F x v^2

94) A motor boat is travelling with a speed of 3.0 m/sec. If the force on it due to water flow is 500 N, the power of the boat is
(a) 150 kW (b) 15 kW
(c) 1.5 kW (d) 150 W

95) An electric motor exerts a force of 40 N on a cable and pulls it by a distance of 30 m in one minute. The power supplied by the motor (in Watts) is
(a) 20 (b) 200 (c) 2 (d) 10

96) A weight lifter lifts 300 kg from the ground to a height of 2 meter in 3

second. The average power generated by him is
(a) 5880 watt (b) 4410 watt
(c) 2205 watt (d) 1960 watt

97) Power of a water pump is 2 kW. If g = 10 m / sec2 , the amount of water it can raise in one minute to a height of 10 m is
(a) 2000 liter (b) 1000 liter
(c) 100 liter (d) 1200 liter

98) From a waterfall, water is falling down at the rate of 100 kg/s on the blades of turbine. If the height of the fall is 100 m, then the power delivered to the turbine is approximately equal to
(a) 100 kW (b) 10 kW
(c) 1 kW (d) 1000 kW

99) From an automatic gun a man fires 360 bullet per minute with a speed of 360 km/hour. If each weighs 20 g, the power of the gun is
(a) 600W (b) 300W
(c) 150W (d) 75W

100) A man does a given amount of work in 10 sec. Another man does the same amount of work in 20 sec. The ratio of the output power of first man to the second man is
(a) 1 (b) 1/2
(c) 2/1 (d) None of these

101) The tidal waves in the sea are primarily due to
(a) The gravitational effect of the moon on the earth
(b) The gravitational effect of the sun on the earth
(c) The gravitational effect of venus on the earth
(d) The atmospheric effect of the earth itself

102) A satellite of the earth is revolving in a circular orbit with a uniform speed v. If the gravitational force suddenly disappears, the satellite will
(a) Continue to move with velocity v along the original orbit
(b) Move with a velocity v, tangentially to the original orbit
(c) Fall down with increasing velocity
(d) Ultimately come to rest somewhere on the original orbit

103) The atmosphere is held to the earth by
(a) Winds (b) Gravity
(c) Clouds (d) None of the above

104) The weight of a body at the centre of the earth is
(a) Zero (b) Infinite
(c) Same as on the surface of earth
(d) None of the above

105) In a gravitational field, at a point where the gravitational potential is Zero
(a) The gravitational field is necessarily zero
(b) The gravitational field is not necessarily zero
(c) Nothing can be said definitely about the gravitational field
(d) None of these

106) The mass of the earth is 6.00 $\times 10^{24}$ kg and that of the moon is 7.40 $\times 10^{22}$ kg. The constant of gravitation G = 6.67 $\times 10^{-11}$ N-m²/kg². The potential energy of the system is -7.79 $\times 10^{28}$ joules. The mean distance between the earth and moon is
(a) 3.80 $\times 10^{8}$ meters
(b) 3.37 $\times 10^{6}$ meters
(c) 7.60 $\times$104 *meters*
(d) 1.90 $\times$102 *meters*

107) If mass of earth is M, radius is R and gravitational constant is G, then work done to take 1 kg mass from earth surface to infinity will be
(a) $\sqrt{\frac{GM}{2R}}$ (b) $\frac{GM}{R}$ (c) $\sqrt{\frac{2GM}{R}}$ (d) $\frac{GM}{2R}$

108) A rocket is launched with velocity 10 km/s. If radius of earth is R, then maximum height attained by it will be
(a) 2R (b) 3R (c) 4R (d) 5R

109) Escape velocity of a body of 1 kg mass on a planet is 100 m/sec. Gravitational Potential energy of the body at the Planet is
(a) – 5000 J (b) – 1000 J
(c) – 2400 J (d) 5000 J

110) A body of mass m kg. starts falling from a point 2R above the Earth's surface. Its kinetic energy when it has fallen to a point 'R' above the Earth's surface [R-Radius of Earth, M-Mass of Earth, [Gravitational Constant]?
(a) $\frac{1}{2}\frac{GmMm}{R}$ (b) $\frac{1}{6}\frac{GMm}{R}$

(c) $\frac{2}{3}\frac{GMm}{R}$ (d) $\frac{1}{3}\frac{GMm}{R}$

111) A body is projected vertically upwards from the surface of a planet of radius R with a velocity equal to half the escape velocity for that planet. The maximum height attained by the body is
(a) R/3 (b) R/2 (c) R/4 (d) R/5

112) Energy required to move a body of mass m from an orbit of radius 2R To 3R is
(a) $GMm/12R^2$ (b) $GMm/3R^2$
(c) GMm/8R (d) GMm/6R

113) The kinetic energy needed to project a body of mass m from the earth surface (radius R) to infinity is
(a) mgR/2 (b) 2 mgR
(c) mgR (d) mgR/4

114) In some region, the gravitational field is zero. The gravitational potential in this region
(a) Must be variable
(b) Must be constant
(c) Cannot be zero
(d) Must be zero

115) A particle falls towards earth from infinity. It's velocity on reaching the earth would be
(a) Infinity (b) $\sqrt{2gR}$ (c) $2\sqrt{gR}$ (d) $zero$

116) The escape velocity for a rocket from earth is 11.2 km/sec. Its value on a planet where acceleration due to gravity is double that on the earth and diameter of the planet is twice that of earth will be in km/sec
(a) 11.2 (b) 5.6 (c) 22.4 (d) 53.6

117) A missile is launched with a velocity less than the escape velocity. The sum of its kinetic and potential energy is
(a) Positive (b) Negative
(c) Zero (d) May be positive or negative depending upon its initial velocity

118) The escape velocity of a projectile from the earth is approximately
(a) 11.2 m/sec (b) 112 km/sec
(c) 11.2 km/sec (d) 11200 km/sec

119) The escape velocity of a particle of mass m varies as
(a) m^2 (b) m
(c) m^0 (d) m-1

120) For the moon to cease to remain the earth's satellite, its orbital velocity has to increase by a factor of
(a) 2 (b) $\sqrt{2}$ (c) $1/\sqrt{2}$ (d) $\sqrt{3}$

121) The escape velocity from the surface of earth is V_e. The escape velocity from the surface of a planet whose mass and radius are 3 times those of the earth will be
(a) V_e (b) $3V_e$ (c) $9V_e$ (d) $27V_e$

122) How much energy will be necessary for making a body of 500 kg escape from the earth
[g = 9.8 m / s2 , radius of earth = 6.4 $\times 10^6$ m]
(a) About 9.8 $\times 10^6$ J
(b) About 6.4 $\times 10^8$ J
(c) About 3.1$\times 10^{10}$ J
(d) About 27.4 $\times 10^{12}$ J

123) The escape velocity for the earth is 11.2 km/sec. The mass of another planet is 100 times that of the earth and its radius is 4 times that of the earth. The escape velocity for this planet will be
(a) 112.0 km/s (b) 5.6 km/s
(c) 280.0 km/s (d) 56.0 km/s

124) Escape velocity on the earth
(a) Is less than that on the moon
(b) Depends upon the mass of the body
(c) Depends upon the direction of projection
(d) Depends upon the height from which it is projected

125) The escape velocity of a rocket launched from the surface of the earth
(a) Does not depend on the mass of the rocket
(b) Does not depend on the mass of the earth
(c) Depends on the mass of the planet towards which it is moving
(d) Depends on the mass of the rocket

126) The velocity with which a projectile must be fired so that it escapes earth's gravitation does not depend on
(a) Mass of the earth
(b) Mass of the projectile
(c) Radius of the projectile's orbit
(d) Gravitational constant

127) The escape velocity for a body projected vertically upwards from the surface of earth is 11 km/s. If the body is projected at an angle of 45° with the vertical, the escape velocity will be

(a) $11/\sqrt{2}$ km/s (b) $11\sqrt{2}$ km/s (c) 22 km/s (d) 11 km/s

ANSWERS WITH EXPLANATION

1) 28% of energy of bread is available to climb
∴ 28% of 21 kJ=5.88kJ
By climbing energy form bread is converted to potential energy of boy=mgh
∴ 5.88kJ=mgh
on substituting m=40 kg, g=10 m/s^2
5.88 × 1000=(40)(10) h
h=14.7 m
Answer: (b)

2) We consider at the surface potential energy is zero
∴ Potential energy lost=Final potential energy - initial potential energy
Potential energy lost=0 - mgh
on substituting values in above equation we get
Potential energy lost=(0.2)(200)10)=400J
Answer:(c)

3) For a circular motion force and displacement are mutually perpendicular. Thus work done is zero
Answer: (c)

4) $KE = \frac{p^2}{2m}$ Form the equation if kinetic energy is constant then p ∝(m)1/2

$$\frac{P_1}{P_2} = \frac{\sqrt{m_1}}{\sqrt{m_2}} \rightarrow \frac{P_1}{P_2} = \frac{\sqrt{25}}{81} \rightarrow \frac{P_1}{P_2} = \frac{5}{9}$$

Answer: (c)

5) Work done=F. S
Work done=(3i + 4j) . (3i + 4j)
Work done=9 + 16=25 Joule
Answer: (b)

6) According to law of conservation of energy
Potential energy=Kinetic energy
mgh=½(mv2)
∴ v=(2gh)1/2
v=19.6 m/s
Answer: (b)

7) relation between Kinetic energy and momentum is given by equation

$$KE = \frac{p^2}{2m}$$

Let P1 be the momentum of first object
P2 be the momentum of first object
now both have same kinetic energy therefore

$$\frac{p_1^2}{m} = \frac{p_2^2}{4m} \rightarrow \frac{p_1^2}{p_2^2} = \frac{1}{4} \rightarrow \frac{p_1}{p_2} = \frac{1}{2}$$

Answer: (d)

1 mm=0.001 m; 40 mm=4 × 10^{-2}m
Force constant k=F / x=10 /0.001=10^4 N/m
Work done=Potential energy of spring
Work done=½(k x^2)
Work done=½ (10^4 × 16 × 10^{-4})
Work done=8 Joule
Answer: (b)

8) W=GMm /R

$$W = \frac{6.67 \times 10^{-11} \times 100}{0.1} \times \frac{10}{1000} \rightarrow 6.67 \times 10^{-11} J$$

Answer: (c)

9) Power=Work / time=(F.S) /t=F (S/t)=F.v
Answer: (b)

10) For recoil of riffle, momentum will be conserved.
MV=mv
V /v=m/M

$$\frac{KE_{riffle}}{KE_{bullet}} = \frac{MV^2}{mv^2}$$

by substituting Value of V/v in the above equation we get

$$\frac{KE_{riffle}}{KE_{bullet}} = \frac{MV^2}{mv^2} \rightarrow \frac{KE_{riffle}}{KE_{bullet}} = \frac{m}{M}$$

as m < M, kinetic energy of riffle < kinetic energy of bullet
Answer: (c)

11) According to Law of conservation of Energy
½(m v_0^2)=mgh
Thus vo2=2gh --(1)
To triple the height let velocity be v'
v'2=2g(3h) --(2)
Take the ratio of eq(2) and eq(1) we get

$$\frac{v'^2}{v_0^2} = 3 \rightarrow v' = v_0\sqrt{3}$$

Answer:(a)

12) Efficiency=output work / input work
output work=mgh=75 × 10 × 3=2250 J
Input work=Force × displacement=250

×12=3000J
∴ Efficiency=2250 / 3000=0.75=75%
Answer: (b)

13) When a work is done upon a system by a conservative force then its potential energy increases
Answer: (d)

14) Initial velocity u=0
F=ma
a=F/m
Now $v2=u2 + 2as$
$v=2(F/m)s$
K.E=½(m)v2
K.E =½(m) × 2(F/m) d=Fd
K.E=constant, and is independent of mass
Answer: (d)

15) Form the law of conservation of momentum, before collision and after collision linear momentum (p) will be same. That is
Initial momentum=Final momentum
∴ $0=m_1v_1 - m_2v_2$
∴ $p_1=p_2$
Now $E=p^2 / 2m$

$$\frac{E_1}{E_2}=\frac{p_1^2}{2m_1}\times\frac{2m_2}{p_2^2}$$

since $p_1=p_2$
$E_1 / E_2=m_2 / m_1$
Answer:(c)

16) since height is same for both balls, their velocities on reaching the ground will be same
thus K.E ∝ mass
$K.E._1 / K.E._2=m_1 / m_2$
$K.E._1 / K.E._2=1/2$
Answer: (d)

17) m : Mass per unit length
∴ rate of mass leaving the hose per sec
≈ mx/ t = mv
Rate of K.E = $½(mv)v^2$
Rate of K.E. = $½m\ v^3$
Answer: (d)

18) According to work energy theorem
W=ΔE
$W=½\ m\ (v_1^2 - v_2^2)$
• $W=½ × 0.01\ [(1000)^2 - (500)2]$
W=3750J
Answer: (b)

19) Power P=work/time
Work W=mgh=m × 10 × 10=100m
P=2000W and t=60s
2000=100m/60
m=1200 kg
since density of water is 1 gm/cc
Volume of water is 1200 liter
Answer: (b)

20) K.E acquired=work done
K.E acquired=F × d
since F is constant , thus K.E is independent of mass
Answer:(d)

21) Given Kinetic nergy of mass m
E_1=kinetic energy of mass 4m E_2
Thus $½\ mv_1^2=½\ 4mv_2^2$
Thus $v_1^2 / v_2^2=4$
Thus $v_1=2v_2$
momentum of mass m is $p_1=mv_1$
momentum of mass 4m is $p_2=4mv_2$
Thus $p_1 / p_2=m × 2v_2 / 4\ m × v_2$
$p_1 / p_2=1/2$
Answer: (c)

22) Kinetic energy is same
kinetic energy is given by formula $E=p^2 / (2m)$
It is given $p_1=p_2$

$$\frac{p_1^2}{2m_1}=4\frac{p_2^2}{2m_2}\rightarrow\frac{m_1}{m_2}=\frac{1}{4}\frac{p_1^2}{p_2^2}\rightarrow\frac{m_1}{m_2}=\frac{1}{4}$$

Answer: (d)

23) Potential energy of spring $U=½\ k × x^2$
Thus for 2cm stretching U=2k
For 10 cm stretching U'=50 k
Thus U'=25U
Answer: (a)

24) Given h=60 m, g=10 ms^2
Rate of flow of water=15 kg/s
∴ Power of the falling water=Change in potential energy per second
Power of the falling water=Rate of flow of water × g × h
Rate of flow of water=15 × 10 × 60=9000 watt
Energy loss 10%=900 watt
∴ Power generated by the turbine=9000 - 900=8100 watt=8.1 kW
Answer:(a)

25) Kinetic energy=potential + Loss in energy
$½\ m\ v^2$=mgh + loss in energy
½ × 1 × (20)2=1 × 10 × 18 + Loss of energy
200=180 + loss of energy
Loss of energy=20 J
Answer: (d)

26) Power exerted by the force is given by P=F × v
When body is just above the earth's surface, its velocity is greatest. At this instant, gravitational force is also maximum. Hence, the power by gravitational force is greatest at the instant just before the body hits the earth
Answer:(b)

27) Mechanical efficiency=Output work / Input energy
The output work will increase because the friction becomes less. Thus the mechanical efficiency increases
Answer: (b)

28) The elastic potential energy=½ × Force × extension
Elastic potential energy=½ × 200 × 0.001=0.1J
Answer: (d)

29) Given : retardation ∝ displacement
Kinetic energy dimension formula=ML^2T^{-2}
Now M and T is constant thus change in kinetic energy ∝ L^2
Change in kinetic energy ∝ x^2
Answer:(c)

30) Work done by such force is always zero thus kinetic energy remains constant
Answer: (a)

31) (a) Work = Force × Displacement (length)
If unit of force and length be increased by four times then the unit of energy will increase by 16 times.

32) (c) No displacement is there.

33) (b) Work done = Force × displacement
= Weight of the book × Height of the book shelf

34) (b) Work done does not depend on time.

35) (d) As the body moves in the direction of force therefore work done by gravitational force will be positive. W = Fs = mgh = 10 × 9.8 ×10 = 980J

36) (b) Work done on the body = K.E. gained by the body
$$F\cos\theta = 1 \Rightarrow F\cos\theta = \frac{1}{s} = \frac{1}{0.4} = 2.5N$$

37) (b) Work done = mgh = 10 ×9.8 ×1 = 98 J

38) (b)

39) (d) Total mass = (50 + 20) = 70 kg
Total height = 20 × 0.25 = 5m
∴ Work done = mgh = 70 × 9.8 × 5 = 3430 J

40) (a) Both part will have numerically equal momentum and lighter part will have more velocity.

41) (d) Watt and Horsepower are the unit of power.

42) (b) Work = Force × Displacement
If force and displacement both are doubled then work would be four times

43) (c) When a force of constant magnitude which is perpendicular to the velocity of particle acts on a particle, work done is zero and hence change in kinetic energy is zero.

44) (a) The ball rebounds with the same speed. So change in it's Kinetic energy will be zero i.e. work done by the ball on the wall is zero.

45) (a) K.E. acquired by the body = work done on the body
$K.E = \frac{1}{2}mv^2 = Fs$ i.e. it does not depend upon the mass of the body although velocity depends upon the mass
$$v^2 \propto \frac{1}{m} \quad [if\ F\ and\ s\ are\ constant]$$

46) (a) As surface is smooth so work done against friction is zero. Also the displacement and force of gravity are perpendicular so work done against gravity is zero.

47) (c) Opposing force in vertical pulling = mg But opposing force on an inclined plane is mg sinθ, which is less than mg.

48) (c) Velocity of fall is independent of the mass of the falling body.

49) (c)
$$P = \sqrt{2mE} \Rightarrow P \propto \sqrt{m}$$
$$\rightarrow (if\ E = constt) \quad \frac{P_1}{P_2} = \frac{m_1}{m_2}$$

50) (c) Work in raising a box
= (weight of the box) × (height by which it is raised)

51) (a)
$$E = \frac{p^2}{2m}\ if\ p = constant\ then\ E \propto \frac{1}{m}$$

52) (a) Body at rest may possess potential energy

53) (b) Due to theory of relativity

54) (d)

$$E = \frac{P^2}{2m} \therefore E \propto P^2$$

i.e. if P is increased n times then E will increase n2 times.

55) (c)

56) (b) According to conservation of momentum.
Momentum of tank = Momentum of shell
$125000 \times V_{tank} = 25 \times 1000 \Rightarrow V_{tank} = 0.2$ ft/sec

57) (d) As the initial momentum of bomb was zero, therefore after explosion two parts should possess numerically equal momentum.



i.e. $m_A v_A = m_B v_B \Rightarrow 4 \times v_A = 8 \times 6 \Rightarrow v_A =$ 12 m/s

$$kinetic\ energy\ of\ other\ mass\ A, = \frac{1}{2} m_A v_A^2 = \frac{1}{2} \times 4 \times (12)^2 = 288j$$

58) (b) Let h is that height at which the kinetic energy of the body becomes half its original value i.e. half of its kinetic energy will convert into potential energy

$$\therefore mgh = \frac{390}{2} \Rightarrow 2 \times 9.8 \times h = \frac{490}{2} \Rightarrow h = 12.5\ m$$

59) (c)

$$P = \sqrt{2mE} \to \ if\ E\ are\ same\ then\ P \propto \sqrt{m}$$

$$\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

60) (a) Let initial kinetic energy, $E_1 = E$
Final kinetic energy, $E_2 = E + 300\%$ of E $= 4E$

$$As\ P \propto \sqrt{E} \Rightarrow \frac{P_2}{P_1} = \sqrt{\frac{E_2}{E_1}} = \sqrt{\frac{4E}{E}} = 2 \Rightarrow P_2 = 2P_1$$

$$P_2 = P_1 + 100\%\ of\ P_1$$

i.e. Momentum will increase by 100%

61) (b)

$P = \sqrt{2mE}$ if E are equal then $P \propto \sqrt{m}$
i.e. heavier body will possess greater momentum.

62) (c)

$$Let\ P_1 = P, P_2 = P_1 + 50\%\ of\ P_1 = P_1 + \frac{P_1}{2} = \frac{3P_1}{2}$$

$$E \propto P^2 \Rightarrow \frac{E_2}{E_1} = \left(\frac{P_2}{P_1}\right)^2 = \left(\frac{\frac{3P_1}{2}}{P_1}\right)^2 = \frac{9}{4}$$

$$\Rightarrow E_2 = 2.25E = E_1 + 1.25E_1$$

$$E_2 = E_1 + 125\%\ of\ E_1$$

so kinetic energy will increase by 125 %.

63) (d)

$$P = \sqrt{2mE} \therefore P \propto \sqrt{E}$$

i.e. if kinetic energy of a particle is doubled the its momentum will becomes $\sqrt{2}$ times.

64) (b) Potential energy = mgh Potential energy is maximum when h is maximum

65) (c) If particle is projected vertically upward with velocity of 2m/s then it returns with the same velocity.

$$so\ its\ kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2} \times 2 \times (2)^2 = 4j$$

66) (b)

67) (c)

$$E = \frac{P^2}{2m}\ if\ bodies\ posses\ equal\ linear\ momenta\ th$$

$$E \propto \frac{1}{m}\ i.e.\ \frac{E_1}{E_2} = \frac{m_2}{m_1}$$

68) (a)

$$P = \sqrt{2mE} \therefore P \propto \sqrt{E}$$

Percentage increase in $P = \frac{1}{2}$ (percentage increase in E)

$$= \frac{1}{2}(0.1)\% = 0.05\%$$

69) (c)

$$kinetic\ energy = \frac{1}{2}mv^2 \therefore k.e \propto v$$

If velocity is doubled then kinetic energy will become four times.

70) (d) In compression or extension of a spring work is done against restoring force. In moving a body against gravity force. In moving a body against gravitational force work is done against gravitational force of attraction. It means in all three cases potential energy of the system

increases. But when the bubble rises in the direction of up-thrust force then system works so the potential energy of the system decreases.

71) (b)

$$E = \frac{p^2}{2m} \text{ if momenta are same then } E \propto \frac{1}{m}$$

$$\therefore \frac{E_1}{E_2} = \frac{m_2}{m_1} = \frac{2m}{m} = \frac{2}{1}$$

72) (d)

$$P = \sqrt{2mE} \text{ if K.E are equal then } P \propto \sqrt{m}$$

i.e., heavier body possess large momentum As $M_1 < M_2$ therefore $M_1V_1 < M_2V_2$

73) (a) $P = \sqrt{2mE} \therefore P \propto \sqrt{E}$

i.e. if kinetic energy becomes four time then new momentum will become twice.

74) (a)

$$E = \frac{p^2}{2m} \text{ if momenta are same then } E \propto \frac{1}{m}$$

i.e. kinetic energy of heavier body will be less. As the mass of gun is more than bullet therefore it possess less kinetic energy.

75) (b) Potential energy of water = kinetic energy at turbine

$$mgh = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 19.6} = 19.6\, m/s$$

76) (c)

$$P = \sqrt{2mE} \therefore \frac{P_1}{P_2} = \sqrt{\frac{m_1 E_1}{m_2 E_2}} \rightarrow \sqrt{\frac{2}{1} \times \frac{1}{8}} = \frac{4}{1}$$

77) (a) The bomb of mass 12kg divides into two masses m_1 and m_2 then

$m_1 + m_2 = 12$ ... (i)

$$\text{and } \frac{m_1}{m_2} = \frac{1}{3} \text{ by solving we get } m_1 = 3\, kg \text{ and } m_2 = 9kg$$

$$\text{kinetic energy of smaller part} = \frac{1}{2}m_1 v_1^2 = 216j$$

$$\therefore v_1^2 = \frac{216 \times 2}{3} \Rightarrow v_1 = 12m/s$$

$$\text{so its momentum} = m_1 v_1 = 3 \times 12 = 36\, kg - m/s$$

As both parts possess same momentum therefore momentum of each part is 36 kg-m/s.

78) (c)

$$P = \sqrt{2mE} \text{ if } m = \text{constant then}$$

$$\frac{P_2}{P_1} = \sqrt{\frac{E_2}{E_1}} = \sqrt{\frac{1.22\,E}{E}} \rightarrow \frac{P_2}{P_1} = \sqrt{1.22} = 1.1$$

$$\therefore P_2 = 1.1\,P_1 \rightarrow P_2 = P_1 + 0.1\,P_1 = P_1 + 10\% \text{ of } P_1$$

So the momentum will increase by 10%.

79) (b) $\Delta U = mgh = 0.2 \times 10 \times 200 = 400\, J$

$\therefore$ Gain in K.E. = decrease in P.E. = 400 J.

80) (a)

$$E = \frac{P^2}{2m} \rightarrow \frac{(2)^2}{2 \times 2} = 1J$$

81) (b) Because 50% loss in kinetic energy will affect its potential energy and due to this ball will attain only half of the initial height.

82) (a)

$$1Kcal = 10^3 Calorie = 4200J = \frac{4200}{3.6 \times 10^6} 1KWh$$

$$\therefore 700kcal = \frac{700 \times 4200}{3.6 \times 10^6} KWh = 0.81\, KWh$$

83) (a)

84) (a)

85) (d) Both fragment will possess the equal linear momentum

$$m_1 v_1 = m_2 v_2 \Rightarrow 1 \times 80 = 2 \times v_2 \Rightarrow v_2 = 40\, m/s$$

$$\text{Total energy of a system} = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2$$

$$= \frac{1}{2} \times 1 \times (80)^2 + \frac{1}{2} \times 2 \times (40)^2 = 4800J = 4.8kJ$$

86) (a)

$$E = \frac{P^2}{2m} \text{ if } P = \text{constant then } E \propto \frac{1}{m}$$

$$\text{According to problem } m_1 > m_2 \therefore E_1 < E_2$$

87) (c)

$$\text{kinetic energy} = \frac{1}{2}mv^2$$

As both balls are falling through same height therefore they possess same velocity

$$but\ KE \propto m \quad (if\ v = constant)$$

$$\therefore \frac{(KE)_1}{(KE)_2} = \frac{m_1}{m_2} = \frac{2}{4} = \frac{1}{2}$$

88) (b)

$$E = \frac{p^2}{2m}\ if\ P = constant\ \ then\ E \propto \frac{1}{m}$$

i.e the lightest particle will possess maximum kinetic energy and in the given option mass of electron is minimum.

89) (a)

$$P = E \Rightarrow mv = \frac{1}{2}mv^2 \Rightarrow v = 2\ m/s$$

90) (a)
91) (a)
92) (a)
93) (c)

$$P = Fv = 500 \times 3 = 1500W = 1.5\ KW$$

94) (a)

$$P = Fv \rightarrow F \times \frac{s}{t} = 40 \times \frac{30}{60} = 20W$$

95) (d)

$$P = \frac{Workdone}{Time} = \frac{mgh}{t} = \frac{300 \times 9.8 \times 2}{3} = 1960W$$

96] (d)

$$P = \frac{mgh}{t} \rightarrow m = \frac{Pt}{gh} = \frac{2 \times 10^3 \times 60}{10 \times 10} = 1200kg$$

$$as\ volume = \frac{mass}{density} \rightarrow v = \frac{1200kg}{10^3 kg/m^3} = 1.2\ m^3$$

$$volume = 1.2m^3 = 1.2 \times 10^3 litre = 1200\ litre$$

97) (a)

$$p = \left(\frac{m}{t}\right) gh = 100 \times 10 \times 100 = 10^5 W = 100kW$$

98) (a)

$$power\ of\ gun = \frac{Total\ kinetic\ energy\ of\ fired\ bullet}{time}$$

$$= \frac{n \times \frac{1}{2}mv^2}{t} \rightarrow \frac{360}{60} \times \frac{1}{2} \times 2 \times 10^{-2} \times (100)^2 = 600W$$

99) (c)

$$power = \frac{W}{t}\ if\ W = constant\ then\ P \propto \frac{1}{t}$$

$$i.e.\ \frac{P_1}{P_2} = \frac{t_2}{t_1} = \frac{20}{10} = \frac{2}{1}$$

100) (a)
101) (b) Due to inertia of direction
102) (b)
103) (a)
104) (a)

$$I = -\frac{dU}{dx}$$

If V = 0, then gravitational field is necessarily zero.

105) (a)

$$U = -\frac{GMm}{r} \Rightarrow 7.79 \times 10^{28}$$

$$= \frac{6.67 \times 10^{-11} \times 7.4 \times 10^{22} \times 6 \times 10^{24}}{r}$$

$$\rightarrow r = 3.8 \times 10^8 m$$

106) (b) Potential energy of the 1 kg mass which is placed at the earth surface

$$= -\frac{GM}{R}$$

⇨ It's potential energy at infinite = 0
⇨ $\therefore$ work done =

$$change\ in\ potential\ energy = \frac{GM}{R}$$

107) (c)
108) (a)

$$v_e = \sqrt{\frac{2GM}{R}} = 100 \Rightarrow \frac{GM}{R} = 5000$$

$$Potential\ energy = U = -\frac{GM}{R} = -5000j$$

109) (b)

$$Potential\ energy = U = \frac{-GMm}{r} = -\frac{GMm}{R+h}$$

$$U_{initial} = -\frac{GMm}{3r}\ and\ U_{final} = -\frac{GMm}{2r}$$

$$Loss\ in\ P.E = Gain\ in\ K.E$$

$$= \frac{GMm}{2r} - \frac{GMm}{3R} = \frac{GMm}{6R}$$

110) (a)

if a body is projected with velocity v ($v < v_e$) then height upto which it will rise, h

$$= \frac{R}{\frac{v_e^2}{v^2} - 1}$$

$v = \frac{v_e}{2}(given) \therefore h = \frac{R}{\left(\frac{v_e}{\frac{v_e}{2}}\right)^2 - 1} = \frac{R}{4-1}$

$= \frac{R}{3}$

111) (d) Change in potential energy in displacing a body from r_1 to r_2 is given by

$$\Delta U = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = GMm\left(\frac{1}{2R} - \frac{1}{3R}\right) = \frac{GMm}{6R}$$

112) (c)

$$\frac{1}{2}mv_e^2 = \frac{1}{2}m2gR = mgR$$

113) (b)

$$I = -\frac{dV}{dr}\ if\ I = 0\ then\ v = constant$$

114) (b) This should be equal to escape velocity i.e. $\sqrt{2gR}$

115) (c)

$$\frac{v_p}{v_e} = \sqrt{\frac{g_p}{g_e} \times \frac{R_p}{R_e}} = \sqrt{2 \times 2} = 2$$

$$\Rightarrow v_p = 2 \times v_e = 2 \times 11.2 = 22.4\ km/s$$

116) (b) If missile launched with escape velocity then it will escape from the gravitational field and at infinity its total energy becomes zero.
But if the velocity of projection is less than escape velocity then sum of energies will be negative. This shows that attractive force is working on the satellite.

117) (c)

118) (c) Because it does not depend on the mass of projectile.

119) (b)

$v_e = \sqrt{2}v_o$ i.e. if the orbital velocity of moon is increased by factor of $\sqrt{2}$ then it will escape out from the gravitational field of earth.

120) (a)

$$v_e = \sqrt{\frac{2GM}{R}} \therefore v \propto \sqrt{\frac{M}{R}}$$

If mass and radius of the planet are three times than that of earth then escape velocity will be same.

121) (c) Potential energy of a body at the surface of earth

$$PE = -\frac{GMm}{R} = -\frac{gR^2m}{R} = -mgR$$

$= -500 \times 9.8 \times 6.4 \times 10^6 = -3.1 \times 10^{10}\ J$

So if we give this amount of energy in the form of kinetic energy then body escape from the earth.

122) (d)

$$Esccape\ velocity = v = \sqrt{\frac{2GM}{R}} \Rightarrow \frac{v_p}{v_e} = \sqrt{\frac{M_p}{M_e} \times \frac{R_e}{R_p}}$$

$$\Rightarrow v_p = 5v_e = 5 \times 11.2 = 56\ km/s$$

123) (d) $v_e = \sqrt{\frac{2GM}{R+h}}$

124) (a)

125) (b)

126) (d) Escape velocity does not depends upon the angle of projection.